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STRATEGIC PLANNING OF FREIGHT TRANSPORTATION IN BRAZIL: METHODOLOGY AND APPLICATIONS

Part 5

APPLICATIONS

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This research was supported by the International Development Research Center of Canada, Grant No. 3-P-82-1012 and in part by research grants NSERC (Canada), FCAR (Québec, Canada) and CNPq (Brazil).

Université de Montréal
Centre de recherche sur les transports - Publication # 642
Juillet 1989

90-01425/

Dépôt légal - 3e trimestre 1989

ABSTRACT

This is the final report of the cooperative project ***Strategic Planning of Freight Transportation in Brazil***, carried out jointly by the Centre de Recherche sur les Transports of the Université de Montréal, the Pontifícia Universidade Católica do Rio de Janeiro and GEIPOT, the National Transportation Planning Company of the Brazilian Ministry of Transportation, with the financial support of the International Development Research Centre (Canada). The report consists of five parts:

Part I	Project Summary
Part II	Methodology: The New Contributions
Part III	The STAN System
Part IV	Specifying Data for the STAN System: Requirements, Concepts, Sources and Estimation Procedures
Part V	Applications.

The fifth and last part of the report is dedicated to the applications realized during the project by using STAN. First, the particular context of strategic freight transportation planning in Brazil is presented. Then, the first application, which deals with the description of the strategic corridors and the demand for transportation in Brazil, is described. The second application, which is the study of the development of the transportation system of the São Francisco corridor concludes the report.

KEY WORDS: Multimode Multiproduct Freight Transportation,
Network Optimization Models,
National/Regional Strategic Analysis and Planning of Freight Flows,
Interactive-Graphic System.

RESUME

Ceci est le rapport final du projet de coopération *Strategic Planning of Freight Transportation in Brazil*, réalisé conjointement par le Centre de recherche sur les transports de l'Université de Montréal, la Pontifícia Universidade Católica do Rio de Janeiro et GEIPOT, l'agence de planification nationale du ministère des transports du Brésil, avec le support financier du Centre de recherches pour le développement international (Canada). Le rapport a cinq parties:

Part I	Project Summary
Part II	Methodology: The New Contributions
Part III	The STAN System
Part IV	Specifying Data for the STAN System: Requirements, Concepts, Sources and Estimation Procedures
Part V	Applications.

La cinquième, et dernière, partie du rapport est dédiée à la présentation des applications réalisées pendant le projet à l'aide du progiciel STAN. Nous rappellons d'abord le contexte particulier de la planification stratégique du système de transport du Brésil. La première application est ensuite décrite. Elle est surtout dédiée à la description des "corridors" stratégiques et de la demande de transport au Brésil. Quant à la seconde application, elle décrit l'étude du développement du système intégré de transport de la région de la rivière São Francisco.

MOTS CLES: Transport multimode multiproduit de marchandises,
Modèles d'optimisation de réseaux,
Planification stratégique nationale/régionale,
Système interactif-graphique.

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CHAPTER ONE

DEFINITION OF STUDY AREAS

In order to meet the objective of developing strategic planning models and tools, it became essential to identify the Brazilian policies and alternatives for freight transportation and the organizations responsible for their conception and implementation. By comparing the economic prospects with the existing transportation system, these policies would reflect the national reality both in the development of the different scenarios and the application of the STAN system.

The evaluation of transportation policies is achieved by transportation systems analysis which takes into consideration three dimensions: the economic dimension. represented by the demand for shiping products between zones and regions and the respective movement costs; the physical dimension, represented by the utilization of the infrastructure; the technological dimension, represented by the modes and their physical-operating characteristics. The middle and long-term horizons, relevant for strategic planning, led to the formulation of scenarios combining these three dimensions.

The strategic planning analyses of the transportation sector, were defined in accordance with the following national macroeconomic goals:

- to improve the stability of prices and to reduce the inflationary process;
- to equilibrate the balance of payments and to generate trade balance surplus. in order to reduce the foreign debt;
- to resume the growth process, in order to overcome recession problems with attendant idle capacity and unemployment.

It is necessary to point out that these macroeconomic goals were considered in the context of scarce resources, principally in the public sector.

The inflationary process revealed the need for identifying policies capable to stimulate the transportation sector's productivity. Resource scarcity made this task highly selective, not only in terms of choosing investment areas, but also in terms of the operation of the system, in order to increase the level of global efficiency of the sector.

The trade balance problem, due particularly to the foreign debt resulting from the petroleum crisis, led to aggressiveness in exporting and to selectivity in importing, in order to increase the domestic capacity of paying the debt. The transportation sector, which determines in part the competitiveness of the final prices for the export/import products, concentrated its efforts on the optimization of routes and the improvement of productivity of the facilities through which these products are moved.

The improvement of the transportation system was also considered as a factor in inducing economic growth in several economic areas. The Brazilian industrial sector is becoming more and more diversified, complex and interdependent. The movement of inputs and final products between industries, and from these to the network that distributes them to the consumer and to the international market, requires a continuous adjustment of transportation. Likewise, the agricultural and cattle-raising sector is expanding its frontier, thus making it mandatory to consider transportation for rural development and agricultural industries. Therefore, the economic expansion becomes feasible only if the transportation of goods for the domestic and foreign markets is assured.

In addition to the expansion of the physical system to meet the demand evolution. the adequacy of the energy profile of the transportation sector was identified as a relevant strategic factor in the macroeconomic context. The energy problem does not result only from the scarcity of energy resources, but also from an inadequacy to satisfy the present demand profile by the available energy sources in Brazil. For the transportation system, the modal assignment of flows, the fleet modifications and the utilization of alternative fuels constitute important factors for increasing its energy efficiency.

In this context, different study areas were identified during the development of the STAN system and, later on, during its application, in order to make it concord with the needs and priorities of the Ministry of Transportation, which is responsible for the guidelines and management of the sectorial policies.

Initialy, the emphasys was the energy sector, with the view of applying the STAN system to the Southeast region, while the remaining regions were considered as interchange regions. The vastness of the national territory and the diversity of the transportation system make it possible, and often necessary, to regionalize the policies and sectorial alternatives. On the other hand, energy consumption was considered in the more general context of the transportation sector strategic planning.

The definition of the Southeast region as the study area reflected not only its economic importance, but also the characteristics of its transportation system, which include anticipated changes in sectorial supply and demand. Its geographical location, large industrial parks, important urban centers and modern ports and terminal linked to the existing railway and highway network, characterize the Southeast as a region catalyzing the transportation flows with origin or destination in it and those crossing it towards other regions or countries.

From the point of view of the demand, the exploration of iron ore in Carajás and the expansion of the agricultural frontier, constitute important factors in the analysis of transportation in the Southeast region. The Carajás iron ore will influence the exploitation of iron ore in the Southeast, which is likely to be limited to meeting the needs of industries within the Southern part of the country, instead of producing a surplus for export. At the same time, the expansion of the agricultural frontier in the Middle-West region and in the Amazonian region, together with the technological modernization of agriculture in the Southeast, caused a considerable increase in the demand for agricultural inputs, principally fertilizers.

From the point of view of the supply, prospects of significant changes in the transportation system were found, which result from the construction of the port terminals of Praia Mole and Sepetiba, the modernization of the Center railway line and the eventual activation of the Ferrovia do Aço (Steel Railway). So, the improvement of its transportation system will produce benefits not only to the region, but also to the other regions with which the Southeast has significant exchanges of transportation flows.

The Southeast region, therefore, was the region selected as the study area for the first application of the STAN system during its development phase, both for the conception and analytical modeling of its transportation system, and for the definition of the information included in the data base (see Part IV). Several freight transportation scenarios were analyzed using this information.

In the phase of implementation of the STAN system, that is, starting from the instalation of its first version at GEIPOT, two types of applications gained prominence: support to the development of GEIPOT projects and to the strategic corridors program. It was guided, in both cases, by the priorities of the Ministry of Transportation, consistent with its objective of developing new strategic planning tools. At the same time, its application to the Southeast region was continued, principally concerning the conceptual and practical definition of the data required and the information sources available.

In the support of GEIPOT projects, the applications were diverse, since the STAN system includes not only a module that assignes freight to transportation networks, but also tools for the analyses of demand projections and modal choice, besides its interactive/graphic capabilities. Among the applications, it is worth pointing out the project "Development of the Inland Waterway Transportation in the Paraná/Paraguai Basin", which had the purpose of identifying a solution to the problems that restrict the utilization of inland waterway transportation. In practical terms, this support consisted of using the STAN system according to the modeling and analysis of the transportation system developed by the project team. In addition, the STAN system was used in the analysis of the North-South Railway flows, other than the interest shown by the Ministry in using STAN in the conception of the Freight Transportation Demand Studies and in the Joint Operation of the Central Line and Steel Railways.

The Strategic Corridors Program (PCE) led to the major application of the STAN system, in compliance with the Transportation Ministry's priorities. The agricultural development policy occupies a special position, as it contributes to meet the social and economic goals of the Government: production at lower costs reduces the cost of the basic foods and makes more competitive the price of surpluses for export. For this purpose, which is strengthened by policies for the agricultural sector, including irrigation, the Strategic Corridors Program appears capable of formulating a set of measures to be implemented in the transportation corridors and making them operational.

The strategic corridors consist of a set of facilities along certain transportation axes, with the purpose of expanding the economic frontier of the country. More precisely, this concept includes the transportation means (all modes), storage facilities and intra- and intersectorial interfaces. Such a transportation structure may be viewed as starting at the coast and gradually penetrating the interior; here it is worth pointing out the corridors defined by the rivers São Francisco, Araguaia/Tocantins, Madeira, and Paraguai, as well as the axis for penetrating the "cerrado" starting from the maritime terminals of the Southeast region, which have recognized strategic potentials. The configuration of these corridors is determined by the formation of pioneer penetration segments, in areas of economic frontier expansion, linked to axes in a consolidation stage, thus creating a basic network for the circulation of freight in the country.

For this purpose, the Strategic Corridors Program included two types of projects: basic studies, to evaluate the effects of cargo flows generated by the occupation of new economic frontiers upon the transportation system; and the studies for making corridors operational, for the proposition of investments and actions for the totality of means and facilities destined to the captivation of the production generated in these new areas. Other than the coherence with the above-mentioned macroeconomic goals. the methodological approach to these projects is very suitable to the utilization of the STAN system. The need for a systemic approach was observed, independent of the partial optimization of modal subsystems or areas of influence, as well as the need for its gradual implantation in accordance with the systematic monitoring of the economic expansion process.

The transportation corridors in the Transportation Sector Development (PRODEST) and the application of the STAN system to the São Francisco corridor are presented in the following chapters. Other than being a priority of the Ministry of Transportation, the inclusion of these applications illustrate different aspects of the utilization of the STAN system.

CHAPTER TWO

THE STRATEGIC CORRIDORS IN TRANSPORTATION PLANNING IN BRAZIL

The transportation system has the objective of providing adequate means for the mobility for people and goods, and thus considers not only the spatial dimension of the economic activity but also its concept as a logistic component in the production-consumption cycle. The economic expansion of the country permits one to more clearly locate development centers, whose sectorial and regional interdependencies characterize transportation activities.

The connections between centers that generate or attract a large density of flows, in actual or potential terms, constitute the so-called Basic National Transportation System (SNBT), which offers a comprehensive and multi-modal view of the system. Other than insuring the flows between two centers, these connections are also used for the transportation of transit (passing-through) flows. This concept, adopted internationally, is intended to guarantee the mobility necessary to the efficient commercialization of the products, both domestically and abroad. Any intervention or modification in one segment will have an impact upon the whole network. This makes it necessary to take into account the interfaces with the storage system when building a representation of the transportation system.

Consequently, the concept of transportation corridors as subsystems of the SNBT was introduced. It corresponds to traffic macrozones, which guarante, within their area of influence, the pick-up, transportation and distribution of the flows in the area, between two or more centers of national relevance. Besides the transportation infrastructure, the transportation corridors include vehicles and equipment, transshipment and storage terminals, some aspects of transportation operations, management, financing, as well as the technological options adequate to their needs. There are several alternative routes that may be followed by flows in each of the corridors.

The concept of transportation corridors was introduced in Brazil in the First National Development Plan (I PND - 1972/74), that implemented a system capable of making the inter- and intra- sectorial investments interact, especially in regions with high production potentials. The interest was then particularly focussed on the agricultural surpluses destined to export, and was substantiated principally by the expansion of the physical infrastructure (improvement of ports and investments on modal systems).

The initial concept was changed in 1979 into that of Export and Supply Corridors, in order to identify areas of influence, and thus to provide means for an efficient operating coordination between the institutions and companies involved. Finally, in 1985, the transportation corridors were considered from a multi-modal, integrated and coordinated viewpoint, articulating all the segments of the commercialization chain. The identification of centers of national relevance allows one to differentiate between *strategic corridors*, important for the expansion of the economic frontier, and *consolidated corridors*, located in more stable economic areas; this differentiation assumed an important role in the Transportation Sector Development Program (PRODEST - 1987/90).

The identification of transportation corridors must therefore be dynamic, following the evolution of the sectorial and spatial profile of the economy, as well as complying with the national integration requirements. In its last form, eight corridors were defined as consolidated, five corridors characterized as strategic, and three new corridors were identified but not yet officialized. Work with these corridors includes three levels: follow-up, short and middle-term studies for a systematic evaluation of the corridors and long-term studies for anticipating structural problems. The latter ones include the application of the STAN system as a strategic planning tool, adequate to evaluate the existing transportation system (through analyses comparing present and future needs according to known or forecasted demand and according to the transportation supply that exists, that is guaranteed by current investments, or that could eventually be implemented), as well as the formulation of alternative solutions for bottlenecks in each corridor. or in their interfaces. Once the utilization of STAN is systematized, including the creation of an information system that is permanently updated, the analyses may become more dynamic.

The consolidated corridors were defined around the coastal states of the South, Southeast and Northeast regions, as well as around the Amazonian region. The areas of influence of corridors of the South region extendend to include neighboring countries, such as Argentina, Uruguay and Paraguay to permit the consideration of the export of grains. The corridors of the Southeast region, on the other hand, include inland states, such as Mato Grosso do Sul and Minas Gerais. Despite the initial conception of only one corridor for the Northeast, the PRODEST (1987/90) divided it into three corridors, depending upon the center considered: Fortaleza, Recife, or Salvador, which is not yet officialized. The Amazonian corridor has the Amazon river as its major transportation axis.

The strategic corridors represent levels of gradual development towards the interior of the transportation system, via pioneer penetration segments into economic frontier areas. Most of these corridors are based on waterway axes, with the other modal systems being in a precarious state: the São Francisco river, the Araguaia and Tocantins rivers in the corridors with the same name, and the watersheds of the Madeira, Amazonas and Paraguai rivers in the Northwest Frontier corridor. The corridors designed to permit the occupation of the meridional part of Brazil, which became feasible due to the expansion of the agricultural frontier for the exports, were designed following this same hierarchical approach: the Cerrado corridor, connected to the Southeast transportation network, and the Cuiabá-Santarém corridor, characterized by the highway axis BR-364. In the future, strategic corridors will be linked to the transportation axes of the consolidated corridors, thus making possible the creation of a basic circulation structure in the country.

Other than the subdivision of the Northeast corridor, PRODEST (1987/90) also proposes the definition of a coastal corridor, whose area of influence covers other corridors that have centers on the coast. This coastal corridor would only include, however, the transportation ways parallelling the Brazilian coast, especially coastal navigation. This corridor plays an important role regarding domestic supply flows and represents the initial development of the transportation sector in Brazil. It is noteworthy that other corridors also present superpositions, principally in attraction zones of inland flows in the Cerrado, Northwest, Cuiabá-Santarém and São Francisco corridors.

The corridor approach constitutes a fundamental strategy for the planning of the transportation sector in Brazil, especially appropriate to its continental size and regional diversity. It also requires to use tools , like the STAN system, which are capable of analyzing the impacts of transportation policies with such a complexity and dimension.

The application of the STAN system to the analysis of the Brazilian transportation system was done at the PRODEST (1987/90) level, that is, principally aimed at the characterization of the Basic National Transportation System (SNBT) and the analysis of demand. The SNBT characterization is taken as reference in the definition of transportation supply at the strategic level for national or regional applications. The demand analysis allows the major flows by product to be identified in the different corridors. To be able to perform the assignment of freight on the network, one has to identify and quantify transportation impedances: operating costs, transportation delays, etc. These are not included in the PRODEST (1987/90) as yet and, consequently, assignments have not been performed in this application. The objective of including the results of this application therefore is to present the national context of freight transportation in the corridor approach, as well as to position the São Francisco corridor in the national context. The São Francisco corridor was the major study area during the Implementation Phase of the STAN system.

Figure 1 shows the geopolitical map of Brazil with the superposition of Export and Supply Corridors. For the consolidated corridors (Rio Grande do Sul, Santa Catarina, Paraná, São Paulo/Santos, Rio de Janeiro, Minas Gerais/Espírito Santo, Northeast I, II and III, and Amazonian) their areas of influence coincide with state borders, whereas the areas of influence of the strategic corridors (São Francisco river, Araguaia-Tocantins rivers, Cuiabá-Santarém, Cerrados and Northwest Frontier) are associated with the basins of major navigable rivers or highway penetration axes. The superposition areas between corridors and the proposed Coastal corridor were not represented.

The identification of the most relevant centers for transportation activities adopted three major criteria:

- generation and attraction of flows that, due to their density, be significant for the economy at a national and regional level;
- location that makes it possible to play a central role of commercial interchange with other countries:

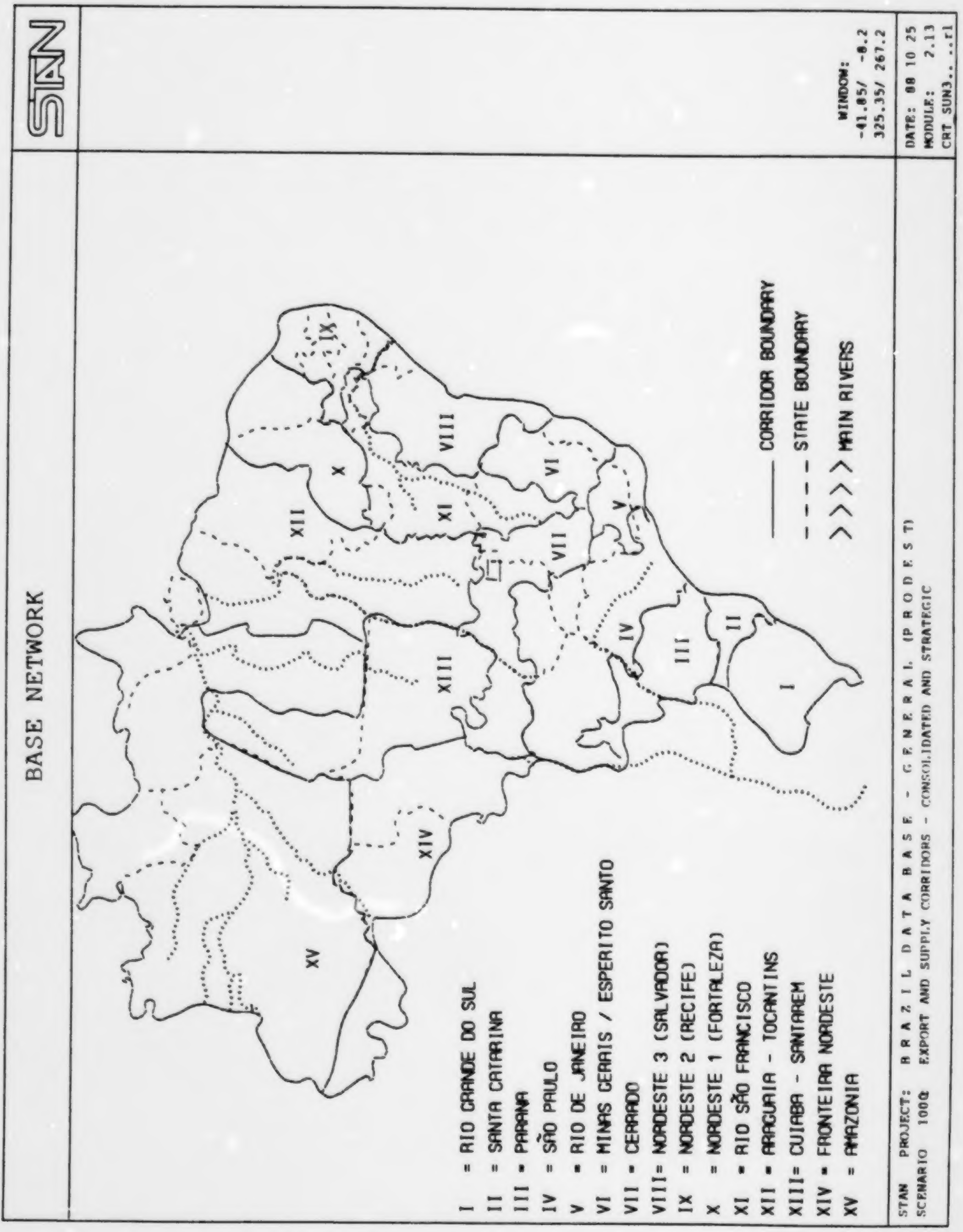
BASE NETWORK
STAN
I = RIO GRANDE DO SUL
II = SANTA CATARINA
III = PARANA
IV = SÃO PAULO
V = RIO DE JANEIRO
VI = MINAS GERAIS / ESPERITO SANTO
VII = CERRADO
VIII= NORDESTE 3 (SALVADOR)
IX = NORDESTE 2 (RECIFE)
X = NORDESTE 1 (FORTALEZA)
XI = RIO SÃO FRANCISCO
XII = ARAGUAIA - TOCANTINS
XIII= CUIABA - SANTAREM
XIV = FRONTEIRA NORDESTE
XV = AMAZONIA
CORRIDOR BOUNDARY
STATE BOUNDARY
MAIN RIVERS
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
XIII
XIV
XV
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
WINDOW:
-41.85/ -0.2
325.35/ 267.2
DATE: 88 10 25
MODULE: 2.13
CRT SUN3.. ..rl

Figure 1 Brazilian Transportation Corridors

- national integration and sovereignty requirements.

Initially, the ten metropolitan regions were defined (Belém, Fortaleza, Recife, Salvador, Belo Horizonte, Rio de Janeiro, São Paulo, Curitiba, Porto Alegre and Brasília) with their comprehensive areas of influence in order to include inter-urban flows. There was also an attempt to aggregate the IBGE micro-regions according to their relevance in terms of generation and attraction of major products, with special emphasis on the location of ports. In Brazil, 102 centers were defined, independent of their distribution in the above-mentioned transportation corridors. In general, the consolidated corridors contained more centers than the strategic corridors (in a 6:3 ratio), due to a more intensive polarization between production and consumption in the economic frontier areas. The extremes were the corridor of São Paulo/Santos with 15 centers and the Amazonian corridor with only 2 centers. Figure 2 shows the geographical distribution of the centers according to the areas of influence of the corridors, as well as the transit nodes necessary to represent the transportation network. It is stressed that the division into areas will be used in the presentation of details about the transportation network.

The characterization of the SNBT for use in the STAN system consisted in a set of nodes and links connecting the centers of national relevance. A strategic network of corridors was defined with a total extension of about 120 000 km, on which Federal Government action would concentrate, whereas the states and municipalities would take care of the feeder system that insures the access to production and consumption centers. Besides the identification of the 102 centers as centroids, the transportation network consisted of 430 nodes and 1823 links, in order to adequately represent the spatial configuration of the transportation system.

The modeling of the SNBT also differentiated the transportation modes, which is important for the definition of operating aspects (vehicles, costs, etc) of transportation

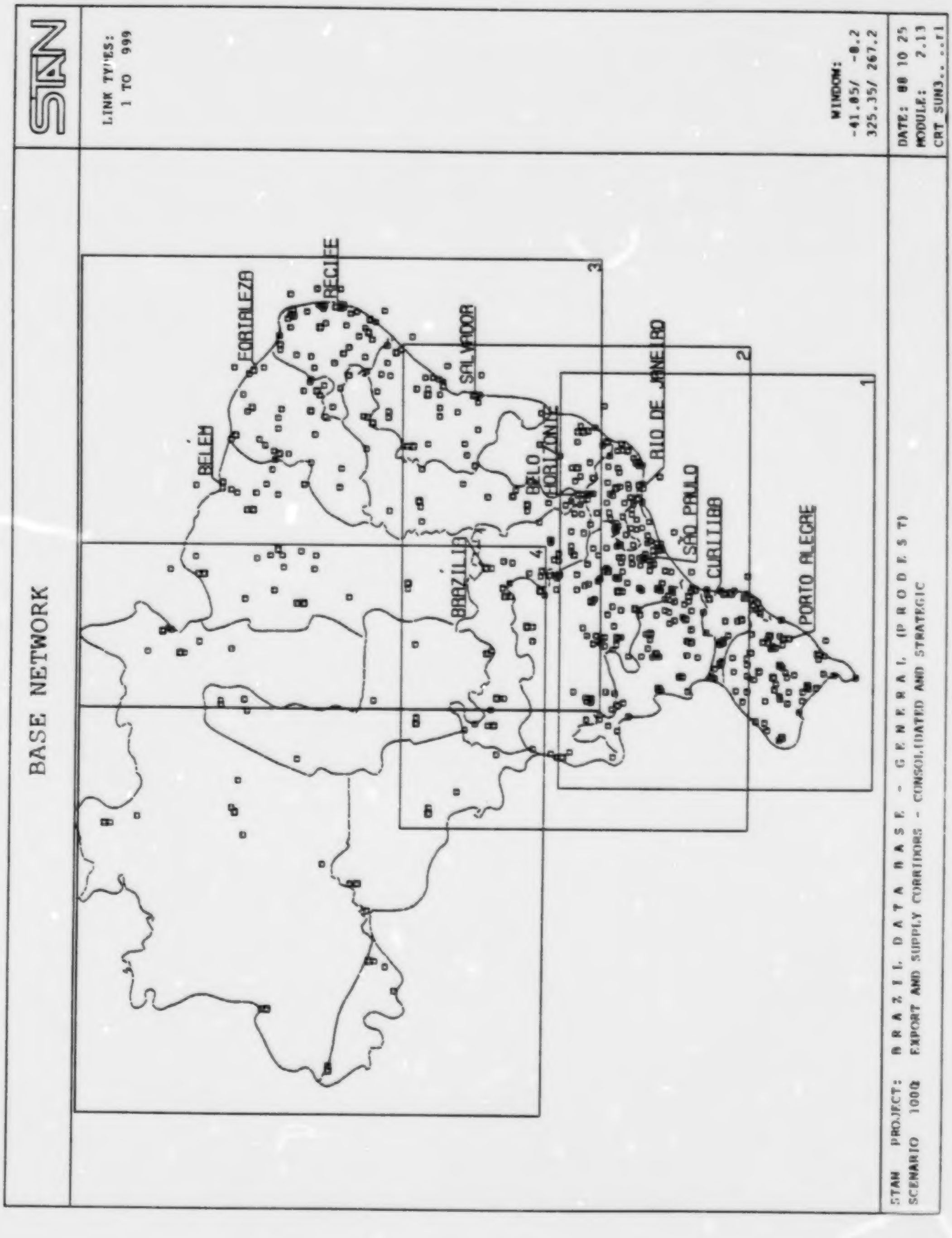
BASE NETWORK
STAN
LINK TYPES: 1 TO 999
WINDOW: -41.05/ -8.2 325.35/ 267.2
DATE: 88 10 25
MODULE: 2.13
CRT_SUN3...rl
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 1000 EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
RECIFE
FORTALEZA
SALVADOR
BELEM
BELO HORIZONTE
RIO DE JANEIRO
SÃO PAULO
CURITIBA
PORTO ALEGRE
BRAZILIA
1
2
3
4

Figure 2 Major Centers in the Transportation Network

activities and of transshipment locations. The route selection should identify the mode or mode combination that best serves each product flow, and evaluate the required transshipments and the interfaces with the storage system. In the national context, six transportation modes were defined: paved (p) and unpaved (t) roads, narrow-gauge railway (e), wide-gauge railway (l), inland navigation waterway (h) and coastal navigation (c). The port access mode (o) was also defined on the links connecting ports with coastal navigation as well as the connecting mode (u) on links between the centroids and the transportation network. On this last mode, the vehicle should display the characteristics of freight collection in the traffic zone, normally associated to road characteristics.

The coding of the link types, used for a selective visualization of the transportation network, included, in addition of the mode (first digit: 1-road, 2-railway, 3-waterway) and the subsystems (second digit: 1-paved, or narrow gauge, or coastal navigation, and 2-unpaved, or wide gauge, or inland navigation, according to the mode), the identification (in the third digit) of federal jurisdiction (1) or state jurisdiction (2) on the road, and RFFSA (1) or other jurisdiction (2) for the railway. The port access modes and the connecting modes were differentiated for waterway and highway, respectively, with the second and third digits equal to zero. Table 1 shows statistics for the number and length of links, by mode and by link type, pointing out the participation of the federal level. One also notes, the definition of 16 maritime ports and 102 centroids in the network modeling the SNBT.

The strategic level representation of the highway network covered 70,000 kilometers, of which more than 80% are paved. Besides its importance for the national integration policy, the highway participates intensively in freight transportation because of the flexibility it offers and the comprehensiveness of its infrastructure. Particularly in the areas of economic frontier expansion, its association to waterway axes is

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STAN  Module: 2.14    Date: 87 05 10   User: GEIPOT--..1v
Project:        BRAZIL DATA BASE - GENERAL (PRODEST)
Scenario 1000: EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
-----------------------------------------------------------------------------------------------------

BASE NETWORK SUMMARY
No. of centroids:              102
No. of regular nodes:          430
No. of links:                 1823
Total link length:       233989.00

MODES
    mode description                   no. of links        link length
p paved road                                815             109863.00
t unpaved road                               96              26505.00
e 1.0m-gauge railway                        498              51661.00
l 1.6m-gauge railway                         92               6980.00
h inland-navigation waterway                 56              26984.00
c coastal-navigation waterway                30              11996.00
o port-access waterway                       32                  0.
u single-mode connectors                    204                  0.

LINK TYPES
link type no.of link link length link type no.of links link length link type no.of links link length
  100      204          0.        111       674      94242.00    112        85       24848.00
  121      141     15692.00       122        12       1811.00    211       388       41892.00
  212       63      3859.00       221        17       1663.00    222         9        1394.00
  231       89      7912.00       232        24       1921.00    300        33         505.00
  310       28     11266.00       320        56      26984.00

FUNCTION CLASSES
fct class  no. of links link length mean capacity fct class no. of links link length mean capacity
   1          1823      233989.00      0.
-----------------------------------------------------------------------------------------------------
```

Table 1 Network Summary

important for the movement of the agricultural production, whereas in economically consolidated areas its modal integration with the railway is more common. Yet, the highway mode is the most affected by the effort of adapting the Brazilian economy to the energy crisis, with a significant reduction of investements that presently are insufficient to even maintain the existing network. It is noteworthy that the paved roads represent less than 10% of the total road network, with a density around 0.16 km/km^2, which shows the great extension of the national territory, but also requires a significant paving effort in order to be comparable to indices of other countries.

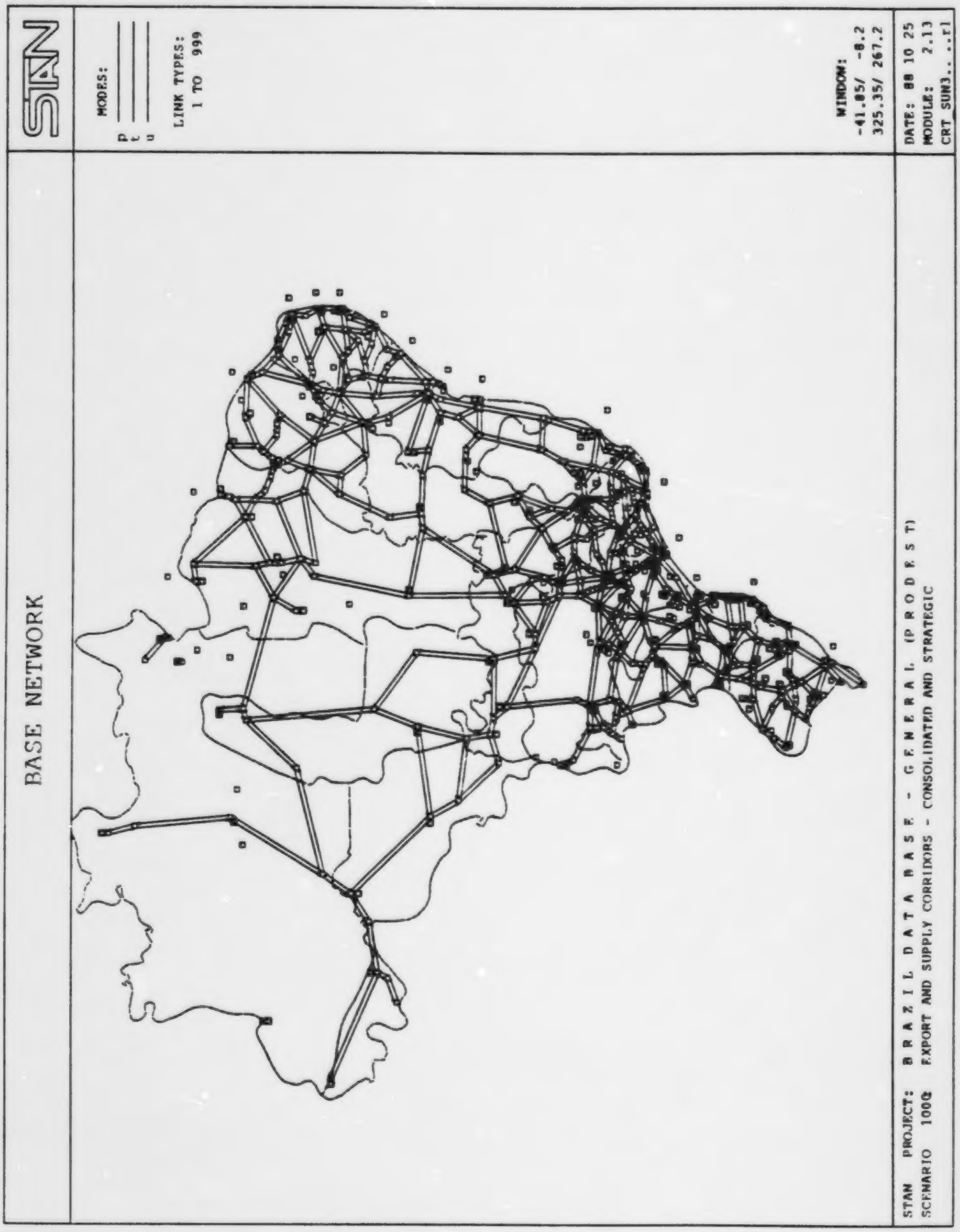
The railway accounts for approximately 30000 kilometers of metric gauge (90% of the total extention). The configuration of the railway network is that of a "fish spine", with its major lines directed to the ports, thus reflecting the historical reasons that determined its construction (exports of raw-materials). Besides the improvement of its operating efficiency, major railway investments are: in consolidated areas, the Ferrovia do Aço (the Steel Railway) in the Rio de Janeiro corridor and the electrification of some FEPASA sections in São Paulo; in expansion areas, the North-South railway and the Transnordestina railway; in the strategic corridors of Araguaia-Tocantins and that of São Francisco river. This effort has the purpose of increasing the participation of this mode in the freight transportation in Brazil.

As to waterway transportation, the port infrastructure plays an important role in terms of domestic supply and foreign trade. The strategic waterway network represents approximately 17% of the SNBT, including inland and coastal navigation. Its participation in freight transportation in Brazil is still small, but possesses a significant expansion potential in the economic frontier expansion areas, without the need for huge investments on infrastructure. As an example, the concentration of 64% of all inland navigation in the Southeast region may be mentioned, whose network length represents only 4% to 5% of the total.

In spatial terms, the transportation network is more dense along the coastal strip, with some highway penetration axes resulting from the national economic development. Figures 3 and 4 present graphs for the highway and railway/waterway transportation networks, clearly depicting the predominance of the highway mode in the SNBT. On the other hand, one notes the consolidation of the transportation infrastutucture in those corridors whose area of influence reaches the coast, whereas for the other corridors the transportation network, still being developed is based on the highway-waterway complementation (see Figures 5 to 8). The road network constitutes an alternative connection to all centroids, while the participation of the railway and waterway systems is more limited.

The SNBT identifies the role of the corridors in the attraction of "native" freight and transit flows. We examine this issue more closely later on. At present, it may be observed that the São Francisco river corridor and the Cerrado corridor constitute important connections between the south of the country and the Northeast and North regions, besides presenting an internal potential for freight generation and attraction. On the other hand, corridors whose area of influence reaches the coast serve transit flows, generated by the foreign trade, through the port system. It is emphasized that the delimitation of the areas of influence of the corridors depends upon the existing transportation system and includes the interventions and investements already scheduled.

The analysis of transportation demand, through the identification of product flows between poles of national relevance forms a feedback loop in the SNBT definition. Once the dimensions of these flows are identified, it is possible to conceive and implement a transportation system that best fits the needs of freight movement between these centers, or a system that reroutes these flows, if this is needed to meet national development policies. In others words, only after identifying the major routes followed


BASE NETWORK
STAN
MODES:
p
t
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LINK TYPES:
1 TO 999
WINDOW:
-41.85/ -8.2
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DATE: 88 10 25
MODULE: 2.13
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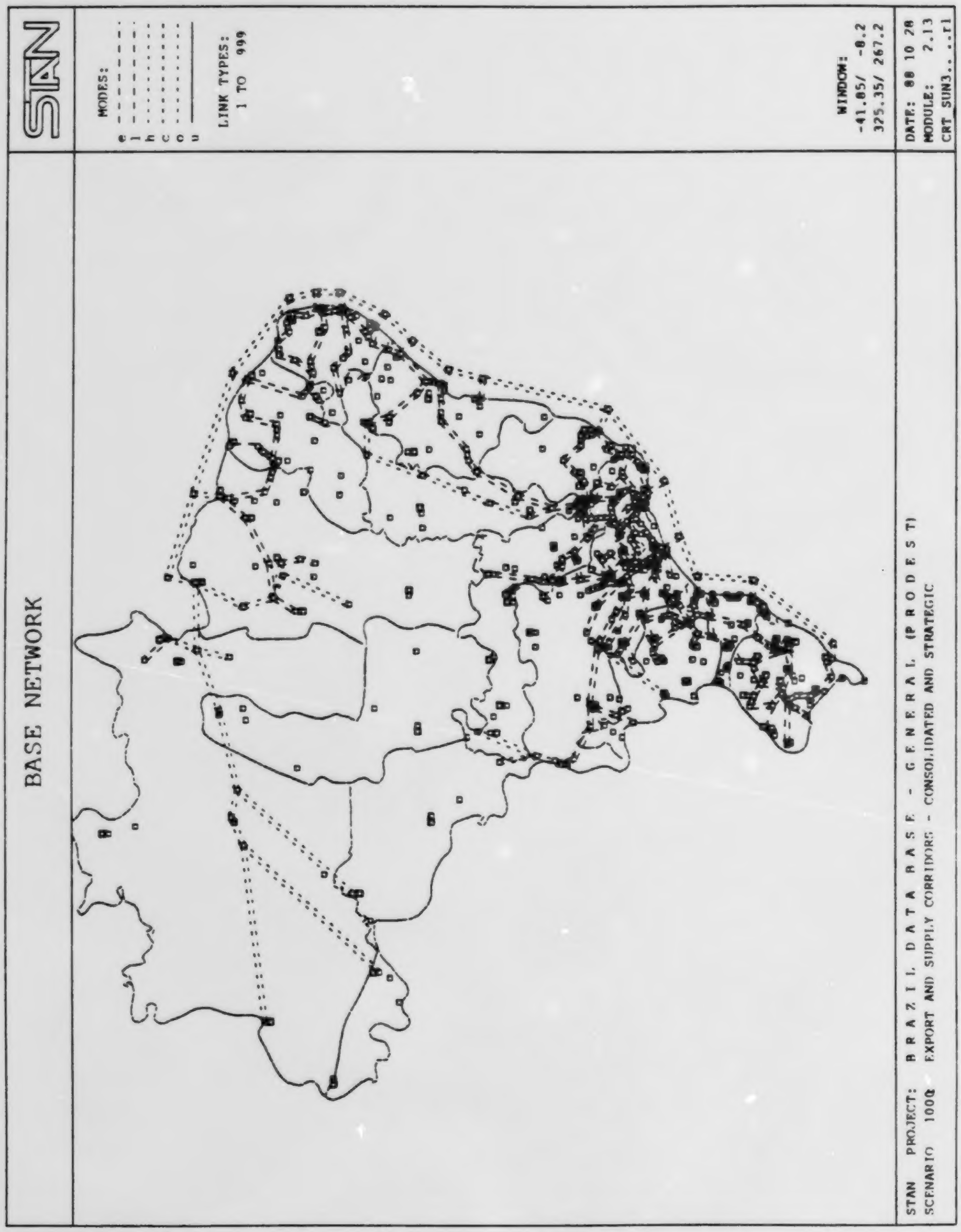
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC

Figure 3 Highway Network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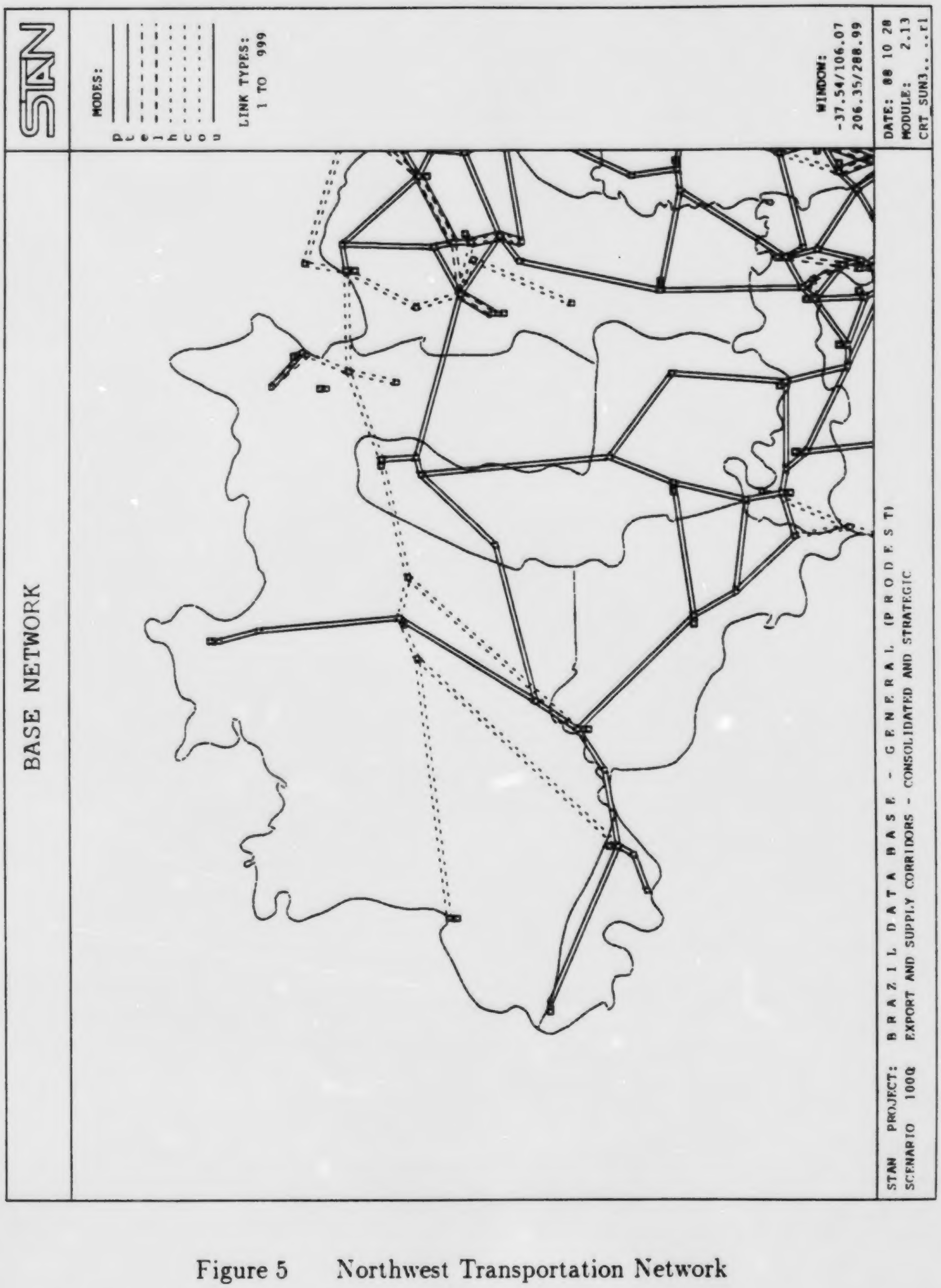
SCENARIO 100Q - EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC

Figure 4 Railway and Navigation Network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SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
DATE: 88 10 28
MODULE: 2.13
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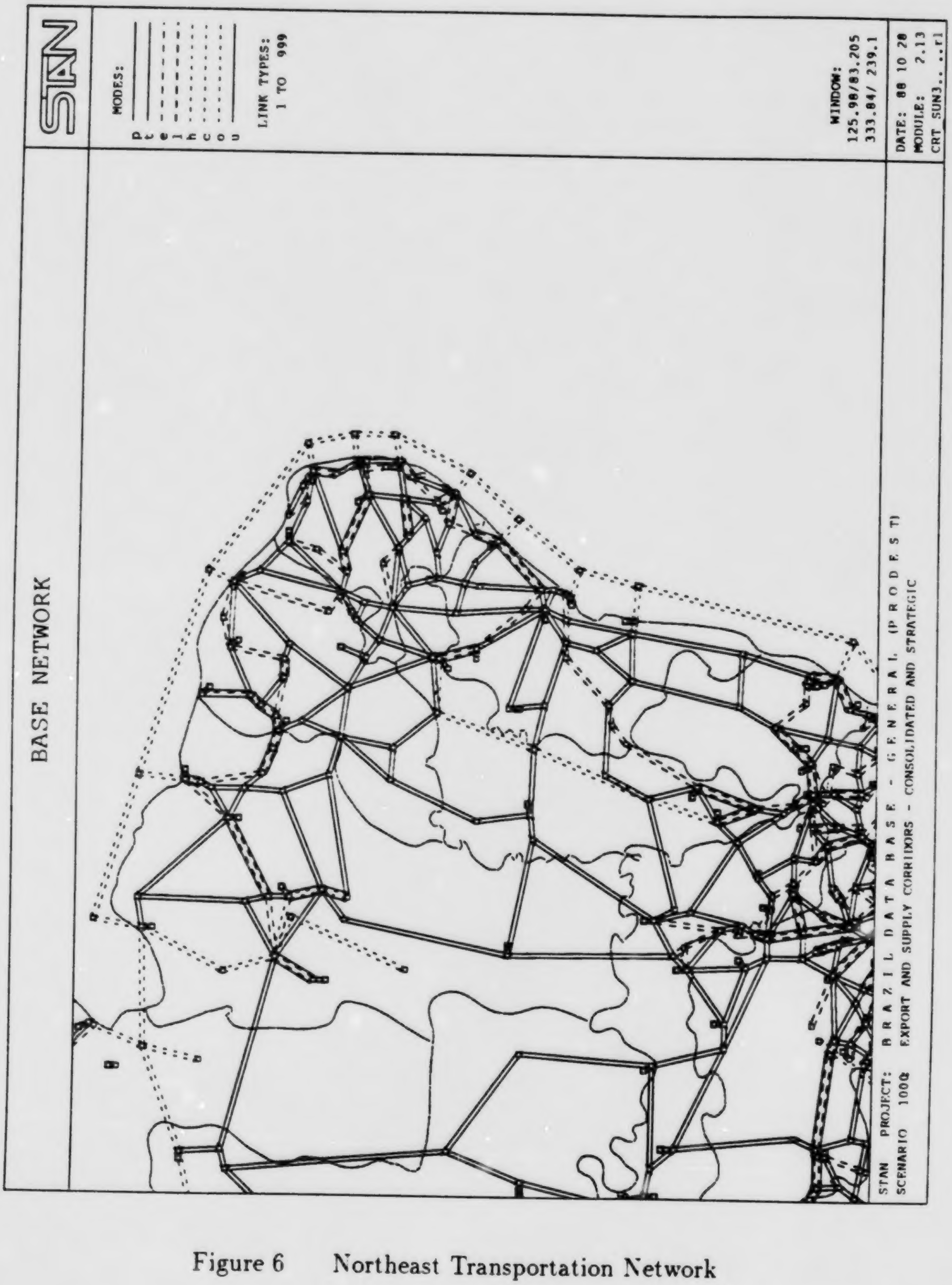
Figure 5 Northwest Transportation Network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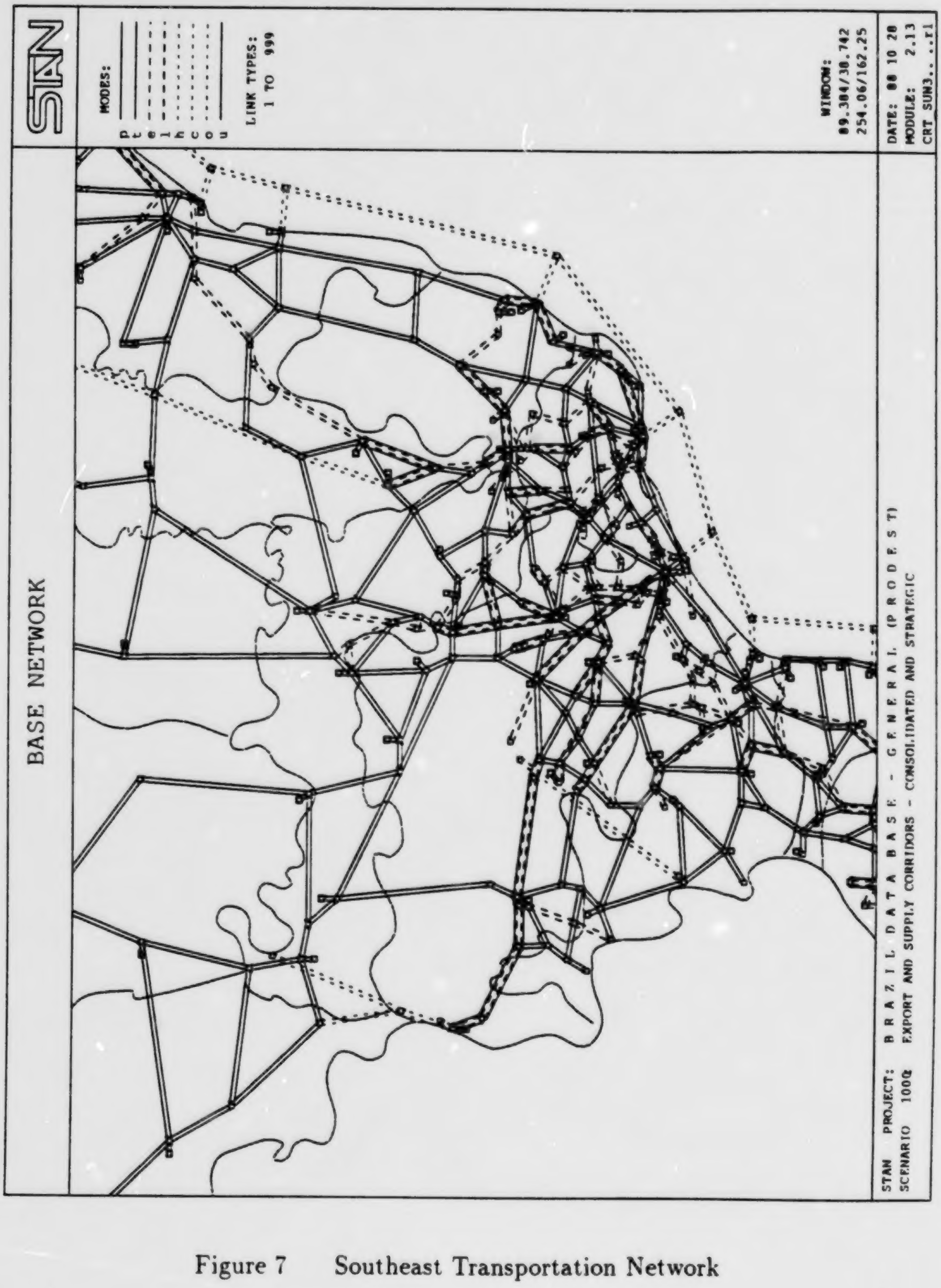
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC

Figure 6 Northeast Transportation Network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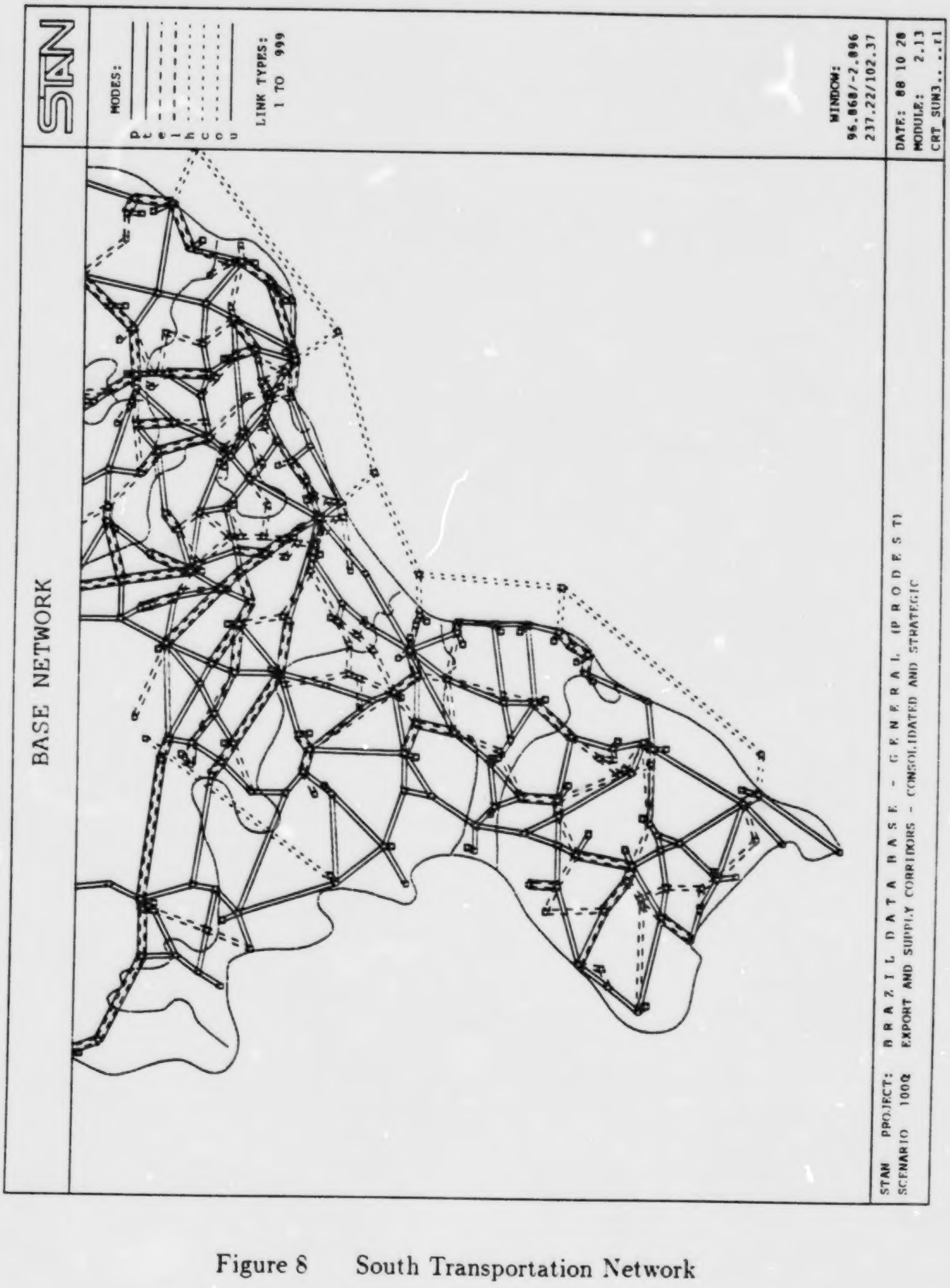
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC

Figure 7 Southeast Transportation Network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STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC

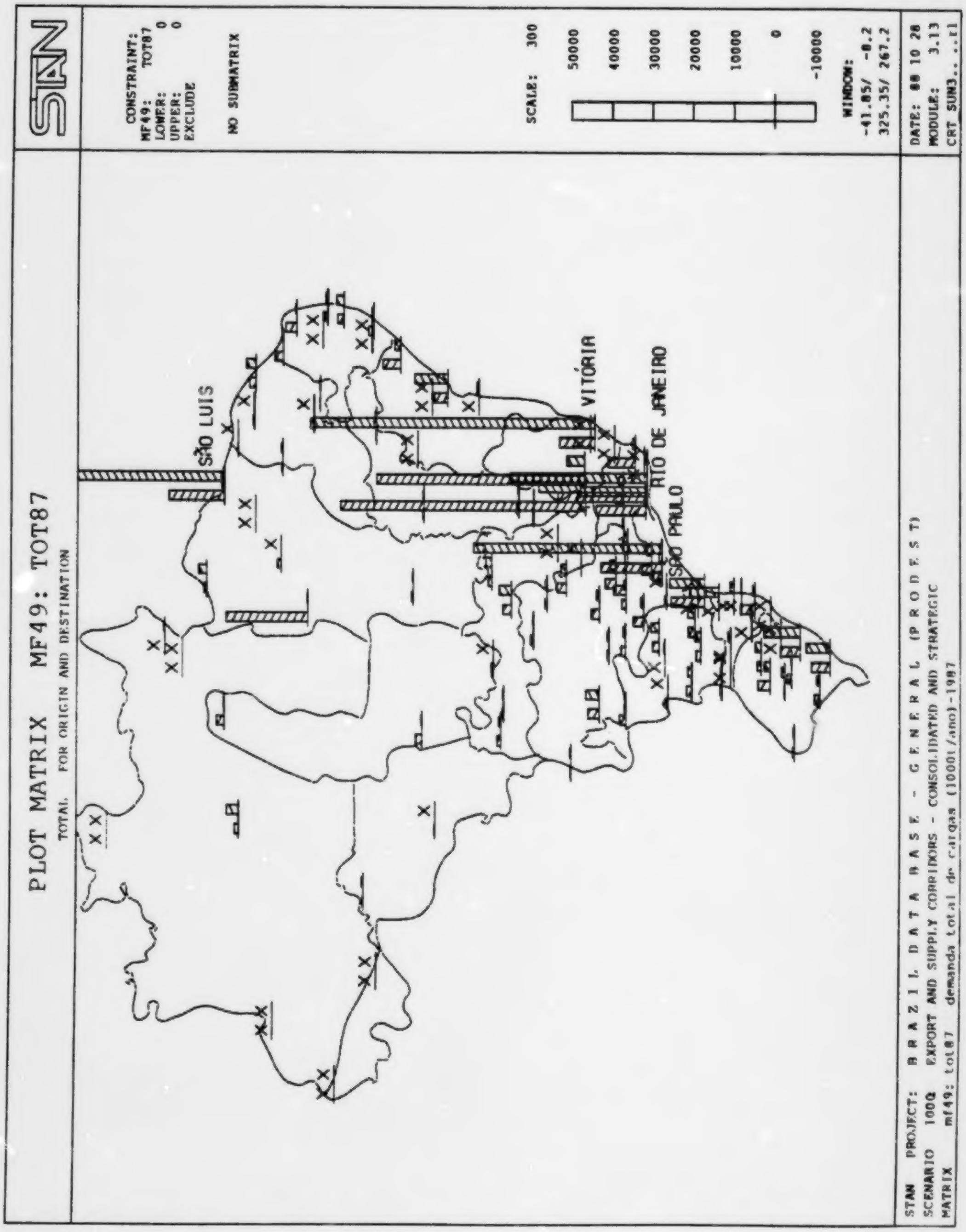
Figure 8 South Transportation Network

by the products, it is possible to validate the modeling of the SNBT. It is important to observe that this is a process of successive approximations, as the quantification of the flows depends upon the centers initially considered.

At a national level, the products were selected according to the magnitude of the flows (above 50,000 t/year), their economic importance, and their production, consumption and comercialization concentration. Twenty products were identified, that constitute the major generators of freight flows: iron ore, petroleum and byproducts, mineral coal, cement, limestones, fertilizers, manganese, bauxite, gypsum, salt, chemical products, alcohol, citric juices, sugar, soyabean and byproducts, rice, corn and wheat.

Major desire lines were initially determined from information provided by modal organizations (SUNAMAM, PORTOBRAS and RFFSA), complemented by GEIPOT studies. The projections for 1987/90 were made by product, based on the forecasts contained in the "Plano de Metas" (Goal Plan) of the Government, as well as on estimates by producing companies and supervising organizations (CFP, CNP, SIDERBRA'S, CVRD, etc.). This information has not been submitted to a detailed validation process, but is adequate for the objective of illustrating the context of freight transportation demand in Brazil.

Figures 9 and 10 display maps with the location of centers/centroids in Brazil and the graphic representation of the total freight volumes generated (left column) and attracted (right column) at these locations in 1987. Larger values are found in centers along the coastal strip, including maritime ports, in accordance with the density of the transportation infrastructure. In fact, the increasing sectorial interdependence of the Brazilian economy indicates a need for integrated planning and developement. The location of some centers is displayed, principally in the north of the country.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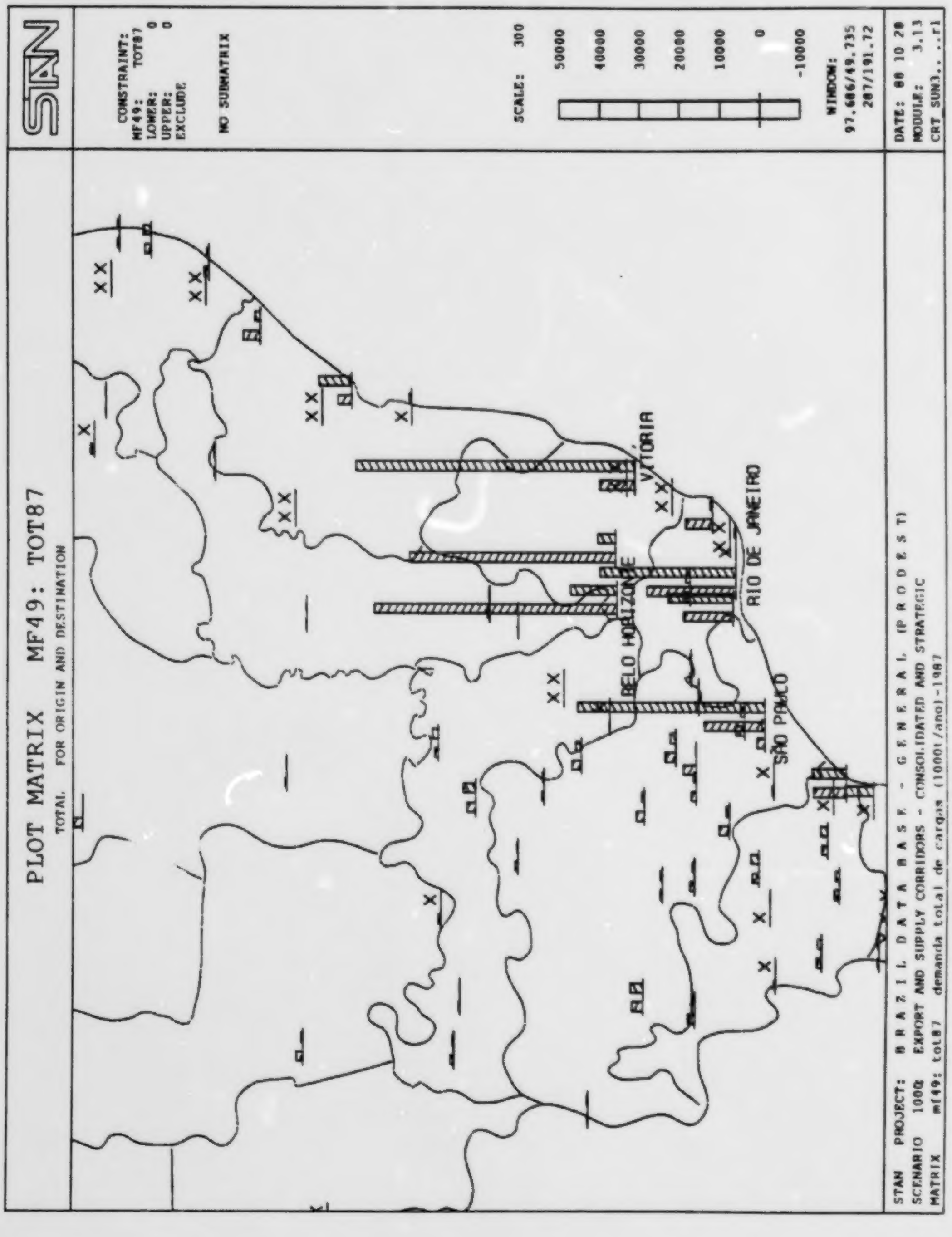
VITÓRIA
RIO DE JANEIRO
SÃO PAULO
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 1000 EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mf49: tot87 demanda total de cargas (1000t/ano)-1987

Figure 9 Major Freight Origin/Destination Centers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SAO PAULO
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SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mf49: tot87 demanda total de cargas (1000t/ano)-1987

Figure 10 Major Freight Origin/Destination Centers (Detail)

even if no associated freight demand is shown (double 'X'), due to their strategic or national security character.

In the quantification of desire lines, average flows of 700,000 tons are observed in 1987, with a very large variation interval (a standard deviation of 2,930,000 t/year) due to the aggregation of different types of freight (general and bulk). On the other hand, structural changes were not identified in the location of freight transportation demand between the years 1987 and 1990, therefore, only an increase in the average quantity transported to 830.000 tons is noted in 1990. Figures 11 and 12 show the histograms of the total O/D matrices for 1987 and 1990, representing the occurence of flows up to 5.000.000 t/year (98% of the total) and over this value (2%), respectively. In the first case, the flow increase occured within the same tonnage intervals, especially between 0 and 1.500.000 t/year. In the second case, an actual flow shift to superior intervals is noted, but with decreased frequencies. On the other hand, taking into account the characteristics of the products (freight lots, storage type, production and consumption dispersion), one observes that the lower the density of the transportation flows, the higher their spatial dispersion. Thus, in order to provide goods with an adequate mobility, the transportation sector should guide its development toward less dense flows, since denser flows may reach the capacity of same parts of the system. It is important to note that, since no additional relevant centers were included in the 1990 projection, and since increased relative distortions may be observed when analyzing the projections, only the 1987 case was the object of the analyses presented in this report.

The centers/centroids were grouped according to their area of influence in the transportation corridors. Fifteen sets of centers were defined, representating the corridors of Amazonia, Araguaia/Tocantins, Northeast III, II and I, Northwest Frontier, Cuiabá/Santarém, Cerrados, São Francisco, Minas Gerais/Espírito Santo, Rio de

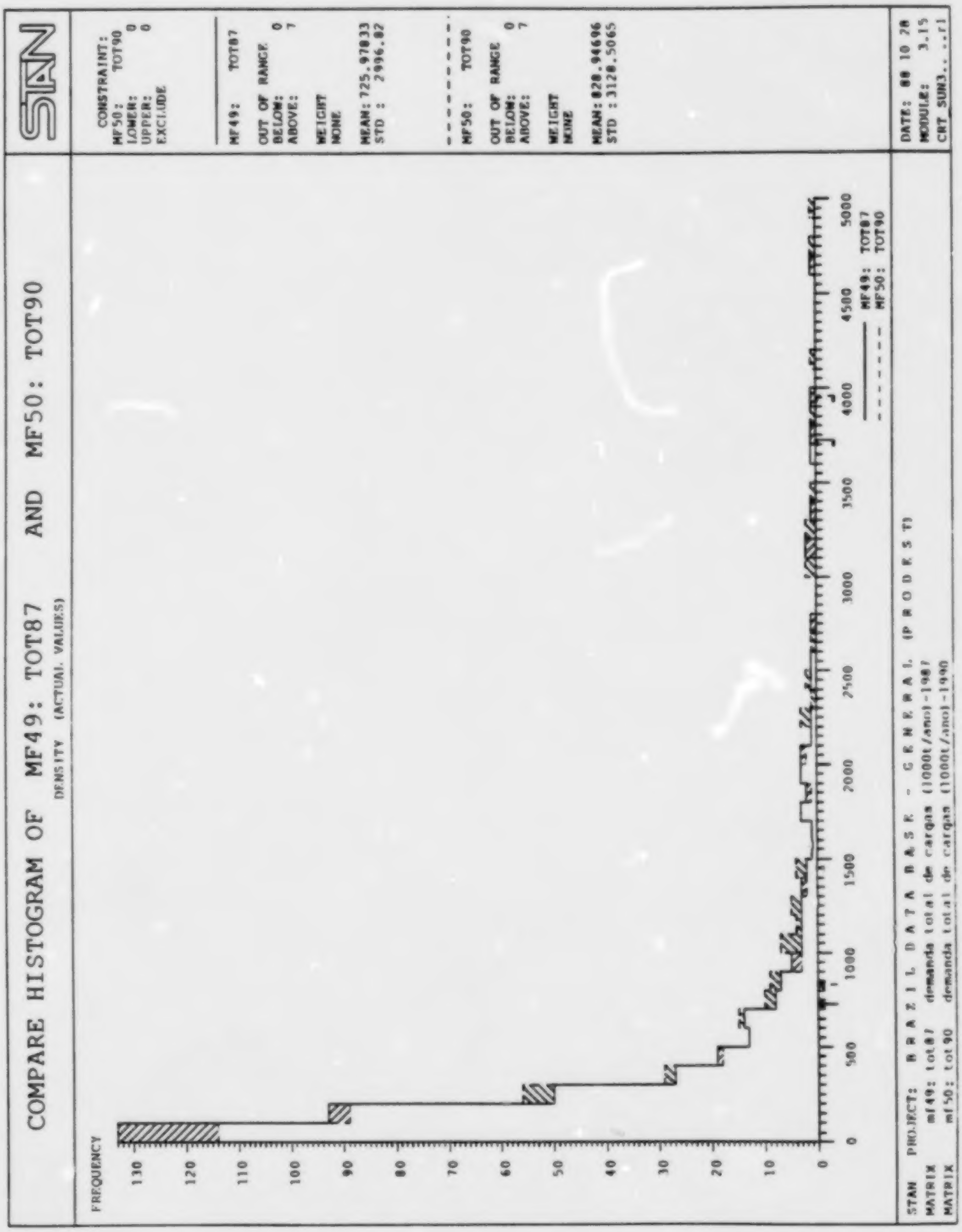


Figure 11 1987-1990 Total O/D Demand Comparison - Bellow 5000000 t/year

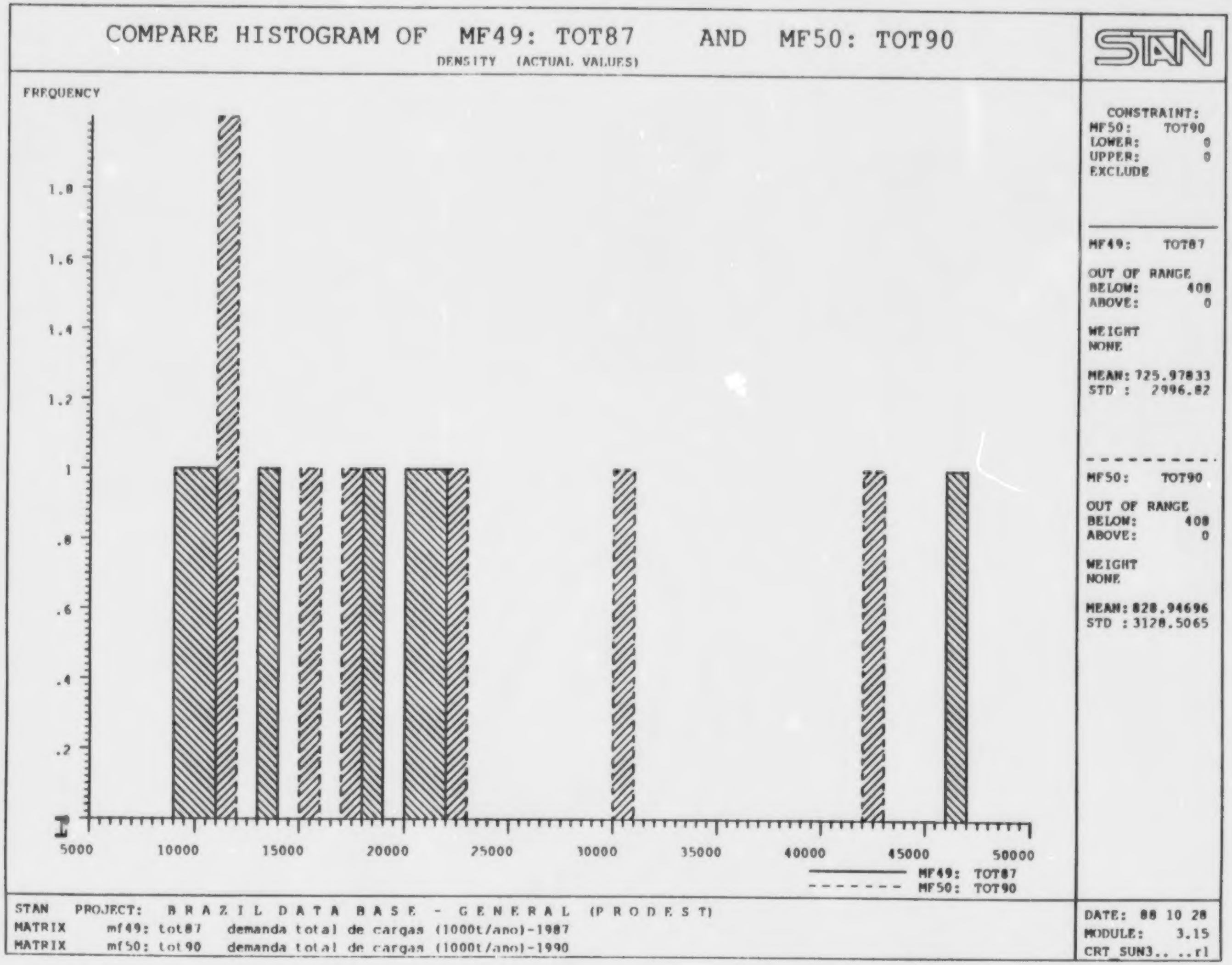


Figure 12 1987-1990 Total O/D Demand Comparison - Over 5000000 t/year

Janeiro, São Paulo/Santos, Paraná, Santa Catarina and Rio Grande do Sul, sequentially numbered in this order. The origin-destination matrix for the 1987 total demand between these groups is shown in Table 2. The last column and line present the total freight generated and attracted in each corridor, for a grand total of 300,000,000 tons transported in 1987.

As already mentioned, transportation demand concentrates in those corridors that reach the coastline, principally when they include important maritime ports. The national economic model, emphasizing exports, is characterized by radial transportation flows from the interior of the country toward loading points, whose high density is due to the predominance of raw materials, such as iron one. In terms of desire lines, one observes that the strategic corridors clearly show interchanges with other corridors, while the consolidated corridors are characterized by a high participation of inland flows (the elements in the major diagonal of the matrix) as a result of the economic development in their areas of influence. It is important to note that the small volume of freight generated or attracted by certain corridors is due either to their strategic geographical location in terms of their potential for expanding the economic frontier (not included in the projection horizons), as in the case of the Amazon and the Northwest Frontier, or to the existence of connections with other corridors, whose transit flows were not identified, as in the case of the São Francisco river and of the Cerrados.

The analysis of total demand presents distortions resulting from the aggregation of flows of different products, whose production and consumption characteristics may influence differently the transportation activities. Despite the fact that 20 products, which were important in terms of freight transportation in Brazil for the PRODEST (1987/90) study, were selected, only the following types were included in order to keep the presentation within a reasonable limits:

Destination Groups

Origin Groups	ga00	ga01	ga02	ga03	ga04	ga05	ga06	ga07	ga08	ga09
ga00	0	0	0	0	0	0	0	0	0	0
ga01	0	0	200	470	0	75	120	60	0	0
ga02	0	486	34430	0	0	95	0	95	390	0
ga03	0	0	113	810	115	1057	0	0	0	45
ga04	0	551	451	313	580	3858	0	0	130	0
ga05	0	451	440	300	658	1140	0	0	0	134
ga06	0	152	0	0	0	0	0	0	50	0
ga07	0	100	1450	0	60	0	0	210	0	0
ga08	0	0	0	0	0	0	0	100	1130	0
ga09	0	0	0	0	0	80	0	0	0	50
ga10	0	0	0	0	0	1125	0	0	1220	0
ga11	0	356	431	205	96	1341	0	0	0	0
ga12	0	732	560	475	604	407	210	450	1695	210
ga13	0	190	112	280	541	295	0	0	0	0
ga14	0	0	185	50	248	265	0	0	0	0
ga15	0	0	205	52	258	378	0	0	0	0
sum	0	3018	38577	2955	3160	10116	330	915	4615	439

	ga10	ga11	ga12	ga13	ga14	ga15	sum
ga00	0	0	0	0	0	0	0
ga01	0	0	75	0	0	0	1000
ga02	110	75	53	0	0	0	35734
ga03	360	200	330	0	0	0	3030
ga04	140	580	921	215	55	170	7964
ga05	106	280	4063	0	0	52	7624
ga06	0	0	0	0	0	0	202
ga07	140	70	1580	770	0	0	4380
ga08	923	0	1489	257	0	0	3899
ga09	50	168	170	0	0	0	518
ga10	74524	33879	8916	185	380	894	121123
ga11	2882	10876	16417	0	5220	5097	42921
ga12	3744	1914	20724	2825	2560	1511	39631
ga13	692	730	1505	8377	1503	1416	15641
ga14	1140	715	800	440	100	0	3943
ga15	796	2635	1061	472	345	10004	16206
sum	85607	52122	58104	14551	10163	19144	303816

Table 2 1987 Total O/D Demand Matrix

- general cargo: cement, metallurgical products, citric juices, pallets, etc.;
- agricultural solid cargo: soya bean and soya meal, rice, corn, wheat, sugar, salt, and fertilizers;
- mineral solid cargo: iron ore, bauxite, manganese, zinc, aluminum, phosphatic rock, lime and gypsum;
- liquid bulk: fuel oils, brut petroleum, petroleum byproducts and alcohol;
- liquid bulk-vegetal oils: soya oil and others.

Tables 3 to 5 show intra- and inter-corridors demand by freight type, the generation and attraction is specified for inter-corridor data, as well as the major products transported.

For general cargo, the demand represents approximately 10% of the total products, with the intra- and inter-corridors flows being roughly the same. Cement is the major product. The analysis by transportation corridor identifies the attraction of products as generating the most significant flow for strategic corridors, whereas the domestic supply flows are the most significant ones for consolidated corridors. In relative terms, the demand for general cargo is almost totally concentrated in the consolidated corridors, between which intense interchange are observed, principally in the Southeast region.

Solid bulk products, which accounts for more than 65% of the total demand, are divided into agricultural and mineral products, the latter representing about 85%, due mainly to the importance of iron ore. If, on one hand, there is a balance between the intra- and inter-corridors flows in the supply of agricultural products, on the other hand, the flows of mineral products are typically intra-corridor due to the location of mines and export maritime ports within the corridors of Minas Gerais/Espírito

Cod. ga	Transport Corridor	Intra-Corridor	Inter-Corridor		Major Products
			Generation	Attraction	
01	Amazônia	— (-)	395 (39.5)	1,281 (42.4)	Several (33)
02	Araguaia-Tocantins	— (-)	581 (44.6)	468 (11.3)	Several (1)
03	Nordeste III	325 (40.1)	113 (5.1)	— (-)	Cement (12)
04	Nordeste II	154 (26.6)	593 (8.0)	144 (5.6)	Cement (5)
05	Nordeste I	105 (9.2)	— (-)	582 (6.5)	Cement (4)
06	Fronteira Noroeste	— (-)	152 (76.2)	120 (36.4)	Several (27)
07	Cuiabá-Santarém	— (-)	— (-)	95 (13.5)	-
08	Cerrado	1,060 (93.8)	— (-)	— (-)	Cement (25)
09	Rio São Francisco	— (-)	248 (53.0)	— (-)	Metal. Products and Cement (23)
10	Minas/Espírito Santo	2,229 (3.0)	758 (14.5)	1,135 (10.2)	Metal. Products and Cement (5)
11	Rio de Janeiro	3,887 (35.7)	3,273 (10.2)	2,2987 (7.2)	Metal. Products and Cement (15)
12	São Paulo/Santos	4,176 (20.2)	1,110 (5.9)	5,776 (15.5)	Metal. Products and Cement (8)
13	Paraná	342 (4.1)	1,281 (17.6)	350 (5.7)	Cement (4)
14	Santa Catarina	— (-)	— (-)	545 (5.4)	-
15	Rio Grande do Sul	225 (2.2)	— (-)	1,021 (11.2)	Cement (3)
	Total	12,503 (7.7)	14,504 (10.3)	14,504 (10.3)	-

Table 3 General Cargo Demand by Corridor (1000t/year (% of total demand))

Cod ga	Transport Corridor	Solid Bulk - Agricultural				Solid Bulk - Mineral			
		Intra-Corridor	Inter-Corridor		Major Products	Intra--Corridor	Inter-Corridor		Major Products
			Generation	Attraction			Generation	Attraction	
01	Amazonia	- (-)	- (-)	(-)	- (-)	(-)	- (-)	100 (3.4)	—
02	Araguaia-Tocantins	805 (2.3)	500 (38.3)	294 (7.1)	Rice (3)	33,625 (97.7)	223 (17.1)	1,840 (44.3)	Iron Ore (84)
03	Nordeste III	- (-)	90 (4.1)	351 (16.4)		125 (15.5)	850 (38.3)	50 (2.3)	Gypsum (19)
04 —	Nordeste II	428 (73.4)	2,877 (39.0)	633 (24.5)	Salt and Sugar (29)	-	-	498 (19.3)	
05	Nordeste I	60 (5.3)	315 (4.9)	658 (7.3)	Sugar (3)	230 (20.1)	-	1,375 (15.3)	Iron Ore
06	Fronteira Noroeste	— (-)	50 (24.8)	70 (21.2)	Fertilizers (7)	- (-)	- (-)	- (-)	—
07	Cuiaba-Santarem	210 (100.0)	2,240 (53.7)	500 (70.9)	Soya bean, Rice and Fertilizers (58)	- (-)	1,930 (46.3)	- (-)	Bauxite (34)
08	Cerrado	70 (6.2)	2,769 (100.0)	3,285 (36.9)	Soya Bean, Rice Corn and Fert. (36)	- (-)	- (-)	- (-)	—
09	Rio São Francisco	—	170 (36.3)	210 (54.0)	Soya Bean and Fertiliz(36)	50 (100.0)	50 (10.7)	45 (11.6)	Gypsum and Quartz (24)
10	Minas/Espirito Santo	175 (0.2)	265 (0.6)	3,666 (33.1)	—	71,768 (96.3)	3,597 (77.2)	3,892 (35.1)	Iron Ore, Lime Rock
11	Rio De Janeiro	673 (6.2)	180 (0.6)	3,278 (8.0)	—	3,543 (32.6)	2,599 (8.1)	32,257 (78.2)	Iron Ore and Mineral Coal
12	São Paulo/ Santos	5,728 (27.6)	7,638 (40.4)	6,021 (16.1)	Soya Bean, Meal Rice and Corn (24)	1,088 (5.2)	455 (2.4)	6,673 (17.8)	—
13	Paraná	6,420 (76.6)	2,827 (38.9)	4,685 (75.8)	Soya Bean, Meal Wheat, Corn and Fertilizers (64)	- (-)	- (-)	552 (9.0)	—
14	Santa Catarina	100 (100.0)	300 (7.8)	1,823 (18.1)	Soya Bean and Sugar(9)	- (-)	3,543 (92.2)	315 (3.1)	Mineral Coal (25)
15	Rio Grande Do Sul	7,261 (72.6)	3,635 (58.6)	362 (4.0)	Soya Bean, Meal Wheat, Fertil Rice and Corn (53)	1,307 (13.1)	2,125 (34.3)	149 (1.6)	Mineral Coal (5)
	Total	21,928 (13.4)	23,836 (16.9)	23,836 (16.9)	—	111,736 (68.6)	47,746 (33.9)	47,746 (33.9)	

Table 4 Solid Bulk Demand by Corridor

Cod. ga	Transport Corridor	Liquid Bulk - Agricultural				Liquid Bulk - Vegetal Oil			
		intra- Corridor	Inter-Corridor		Major Products	Intra- -Corridor	Inter-Corridor		Major Products
			Generation	Attraction			Generation	Attraction	
01	Amazonia	— (-)	605 (60.5)	1,479 (49.0)	Petroleum & Byproducts)	— (-)	— (-)	158 (5.2)	-- —
02	Araguaia- -Tocantins	— (-)	— (-)	1,545 (37.3)	Petroleum Byprod (3)	— (-)	— (-)	— (-)	—
03	Nordeste III	— (-)	1,167 (52.5)	1,744 (81.3)	Petroleum Byprod. & Alcohol(45)	360 (44.4)	— (-)	— (-)	several (13) —
04	Nordeste II	— (-)	3,914 (53.0)	1,249 (48.4)	Petroleum Byprod. & Alcohol(50)	(-) (-)	(-) (-)	56 (2.2)	—
05	Nordeste I	745 (65.4)	6,169 (95.1)	4,987 (55.6)	Petroleum Byprod. & Alcohol(66)	(-) (-)	(-) (-)	1,374 (15.3)	— —
06	Fronteira Noroeste	— (-)	— (-)	140 (42.4)	Petrolnem Byprod.(61)	— (-)	— (-)	— (-)	—
07	Cuiaba- Santarem	— (-)	— (-)	110 (15.6)	—	— (-)	— (-)	— (-)	—
08	Cerrado	— (-)	— (-)	2,200 (63.1)	Petroleum Byprod.(22)	— (-)	— (-)	— (-)	—
09	Rio Sao Francisco	— (-)	— (-)	134 (34.4)	—	— (-)	— (-)	— (-)	—
10	Minas Gerais/ /Espirito Santo	352 (0.5)	3,605 (7.7)	2,190 (19.8)	Petroleum Byprodu.(4)	— (-)	— (-)	200 (1.8)	—
11	Rio de Janeiro	2,773 (25.5)	24,044 (75.0)	2,100 (5.1)	Petroleum Byprod.(21)	— (-)	1,969 (6.1)	624 (1.4)	—
12	Sao Paulo/ Santos	9,732 (47.0)	8,805 (46.5)	18,910 (50.6)	Petroleum Byprod. & Alcohol(50)	— (-)	822 (4.8)	— (-)	—
13	Parana	1,615 (19.3)	1,615 (22.2)	587 (9.5)	Petroleum Byprod & Alcohol(15)	— (-)	1,541 (21.3)	— (-)	several (4)
14	Santa Catarina	— (-)	— (-)	5.830 (67.9)	Petroleum Byprod.(46)	— (-)	— (-)	550 (5.5)	—
15	Rio Grande Do Sul	1,211 (12.1)	— (-)	5,719 (62.5)	Petroleum Byprod. & Alcohol(21)	— (-)	442 (7.1)	1,889 (20.7)	—
	T O T A L	16,428 (10.1)	49,924 (35.5)	49,924 (35.5)	—	360 (0 2)	4,851 (3 4)	4,851 (3,4)	

Table 5 Liquid Bulk Demand by Corridor

Santo, Rio de Janeiro and, more recently, Araguaia/Tocantins (the Carajás ore). In the case of agricultural bulk products, soya bean, wheat, corn and rice are the major products, with the production zones located in the strategic corridors and in the south of the country, while the processing and export centers are concentrated in the more economically consolidated regions. The inclusion of fertilizer flows as agricultural flows is due to their interdependence with this sector.

Finally, liquid bulk products represent 24% of the transportation demand, with almost the totality of the flows made up by petroleum and its byproducts. Vegetal oil characterize inter-corridors flows generated principally in the South region for the supply of kitchen consumption. Similarly, the concentration of petroleum refineries and import ports, as well as the dispersion of consumption throughout the national territory, determined the radial transportation flows for its byproducts.

To assist more detailed analyses, at the end of this section plots representing the transportation demand by type of cargo are presented, both for the total generated and attracted flows at centroids and for the corresponding desire lines (see Figures 18 to 27). The superposition of the two types of plots permits to identify the interchanges between the centers, based on their characterization as production or consumption centers for each freight type. In general, the desire lines are spatially complex and homogeneous in terms of quantity transported, with the exception of iron ore, which, despite the dispersion of metallurgical plants, presents larger flows towards maritime ports.

While an extensive validation analysis was not performed for the O/D matrices in the national context, the STAN system was used to check the sectorial interdependencies observed for the selected products. In other words, the STAN system verified if the quantities of products input at a center are sufficient to generate the final product output, according to transformation coefficients. The results did not indicate significant differences in the balancing equations that could justify a redistribution of the flows. As an example, an analysis is presented for soya bean and its byproducts, soya meal and soya oil.

Initially, the destinations of soya bean flows were identified, as well as the origins of its byproducts for the year 1987 (see Figures 13 to 15). Through the coefficients of transformation of beans into oil (19%) and into meal (73%), the matrix of grain demand of the processing industries were determined. A larger value was adopted when meal and oil were producted in the same center. The difference between the grain matrix. aggregated by destination. and the industry-demand matrix. aggregated by origin. corresponds to the balancing of soya production.

Figures 16 and 17 show these difference at their locations and on the histogram. The excess in the supply of grains indicated. in most cases. export flows by maritime ports. whereas deficits in the industries pointed to the need to verify the available stocks. before any redistribution of flows. From the histogram. it may be noted that the average of the differences is of -425 tons, with the deficits presenting a small total frequency and not exceeding 900 throusand tons/year.

Therefore. the PRODEST (1987/90) consists of a systemic approach to transportation. both in the regional. through the characterization of corridors. and the sectorial aspect, through the product demand analysis. The SNBT was defined in a multi-modal perspective. so as to provide an adequate mobility to the goods. Interventions and investments on the SNBT are a responsability of the federal government. If, on one hand, the national economic development inserts an increased dynamism in the transportation sector (and a need for monitoring the expensive and normally indivisible government programs). on the other hand. the transportation sector must anticipate the expansion of the economic frontier, while guaranteeing its effectiveness. Similarly, the efficiency of the transportation operation contributes to make the products competitive in the domestic market and abroad.

The corridors approach, based on the coordination of investments and operation of all the agents involved in the commercialization of the products, permits a balance to be achieved between transportation supply and demand, with a regionalization adequate to the activity. The development of the transportation sector, as a derived activity, depends upon the sectorial interdependencies or, in a more comprehensive manner, upon the spatial relations between production and consumption in the national economy. It should, however also include modal alternatives when choosing the routes, as well as the respective interfaces with the storage system. The applications of the STAN system are to be seen in this context: not only to monitor the national economy, through the analyses and projections of demand, but also to identify the utilization of the transportation system according to efficiency parameters defined by users (costs, time, energy consumption and others) that indicate priority actions and investments.

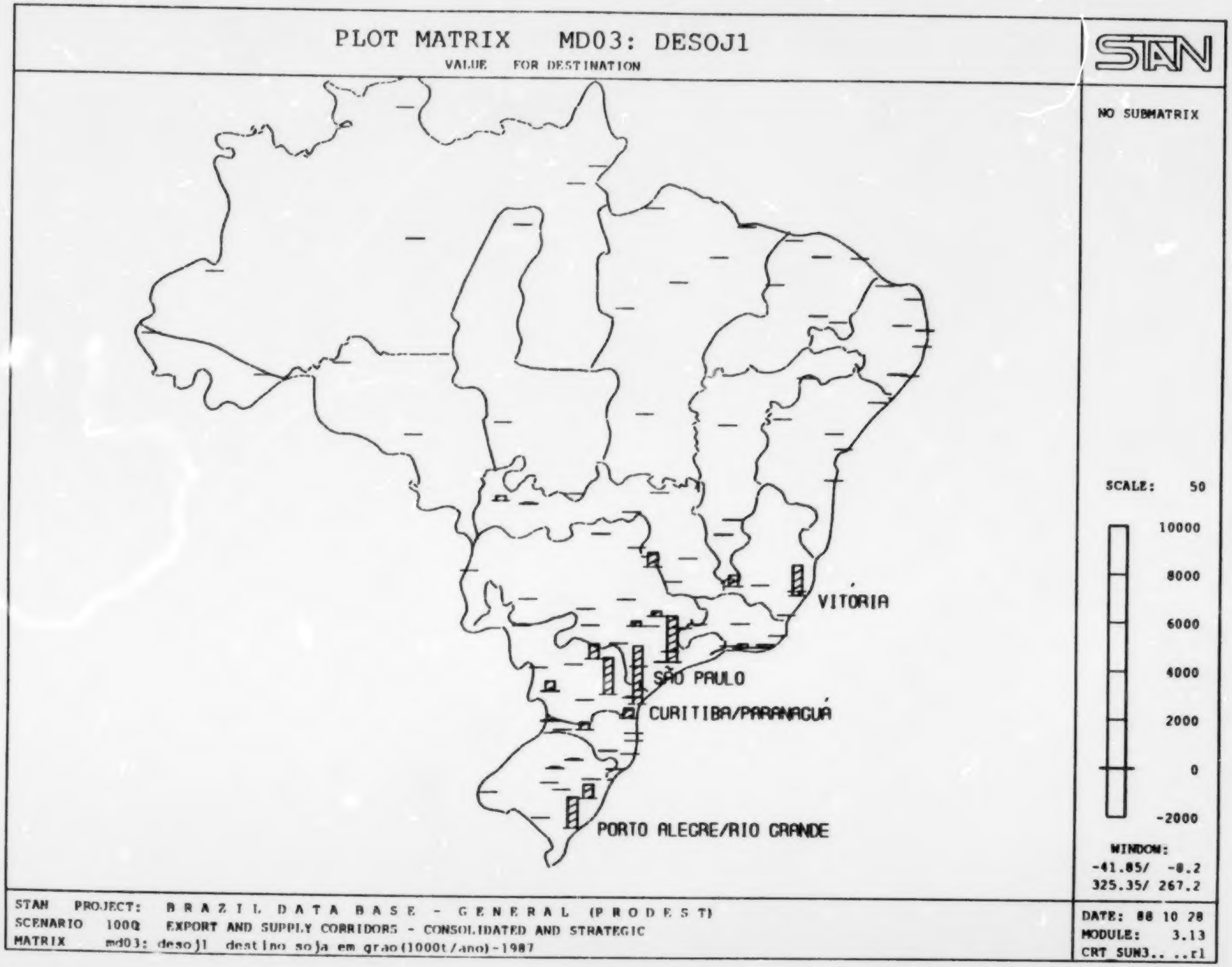

PLOT MATRIX MD03: DESOJ1
VALUE FOR DESTINATION
STAN
NO SUBMATRIX
SCALE: 50
10000
8000
6000
4000
2000
0
-2000
WINDOW:
-41.85/ -8.2
325.35/ 267.2
VITORIA
SÃO PAULO
CURITIBA/PARANAGUÁ
PORTO ALEGRE/RIO GRANDE
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX md03: desoj1 destino soja em grao(1000t/ano)-1987
DATE: 88 10 28
MODULE: 3.13
CRT_SUN3.. ..rl

Figure 13 Soya Bean Demand

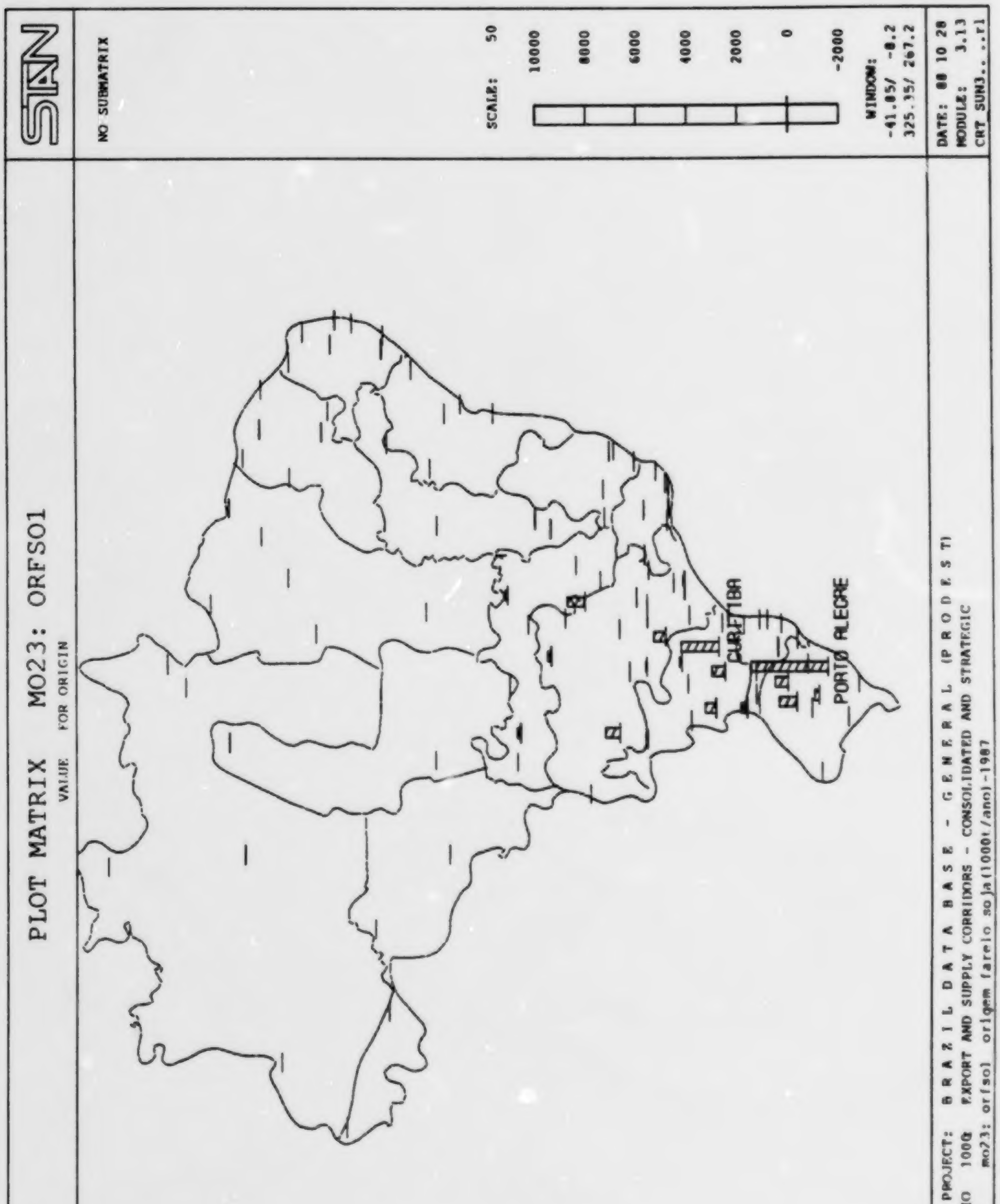

STAN
PLOT MATRIX MO23: ORFSO1
VALUE FOR ORIGIN
NO SUBMATRIX
SCALE: 50
10000
8000
6000
4000
2000
0
-2000
WINDOW:
-41.05/ -8.2
325.35/ 267.2
CURITIBA
PORTO ALEGRE
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mo23: orfsol origem farelo soja(1000t/ano)-1987
DATE: 88 10 28
MODULE: 3.13
CRT SUN3.. ..rl

Figure 14 Soya Meal Supply

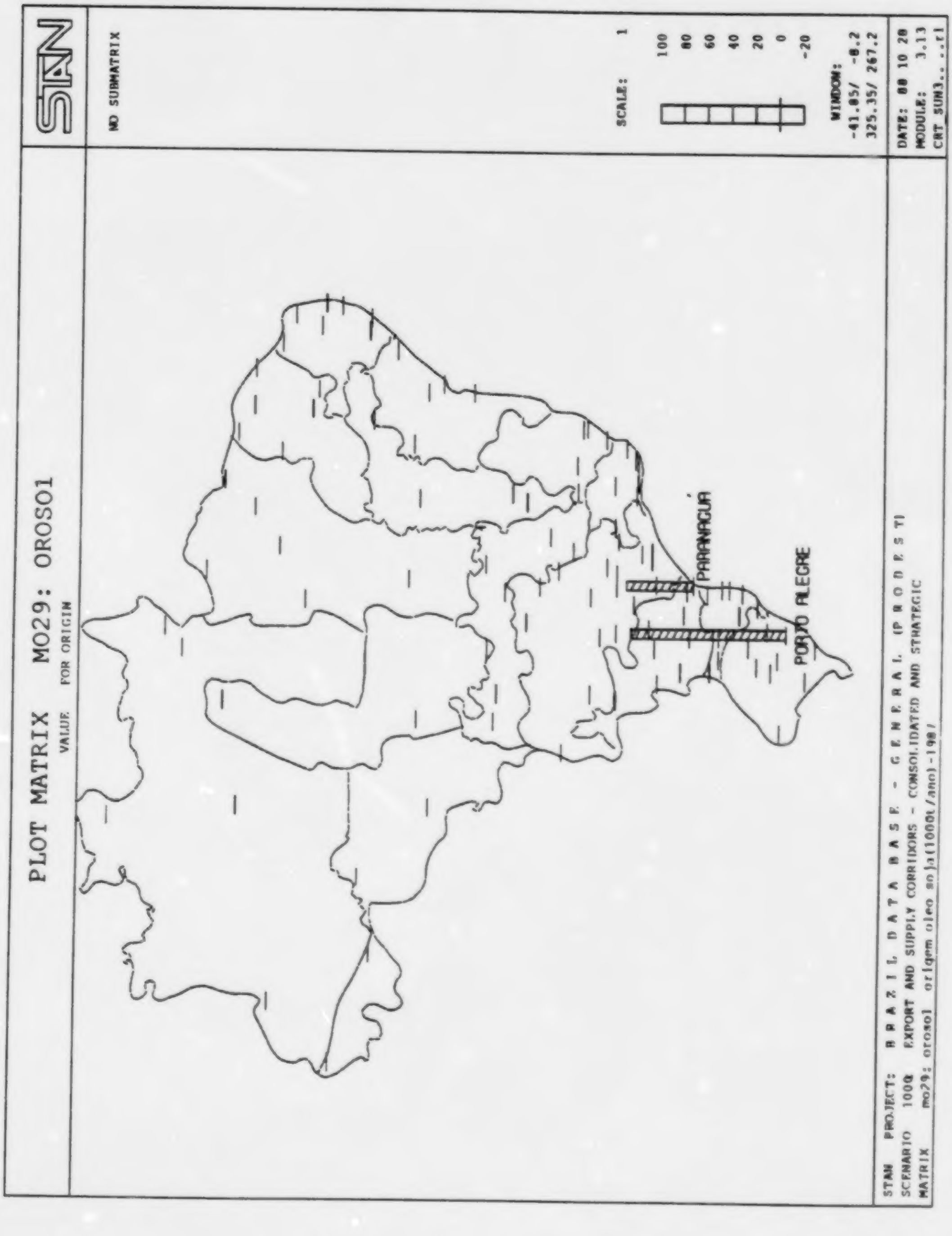

STAN
PLOT MATRIX M029: OROSO1
VALUE FOR ORIGIN
NO SUBMATRIX
SCALE: 1
100
80
60
40
20
0
-20
WINDOW:
-41.05/ -8.2
325.35/ 267.2
PARANAGUA
PORTO ALEGRE
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mo29: oroso1 origem oleo soja(1000t/ano)-1987
DATE: 88 10 28
MODULE: 3.13
CRT SUN3.. ..rl

Figure 15 Soya Oil Supply

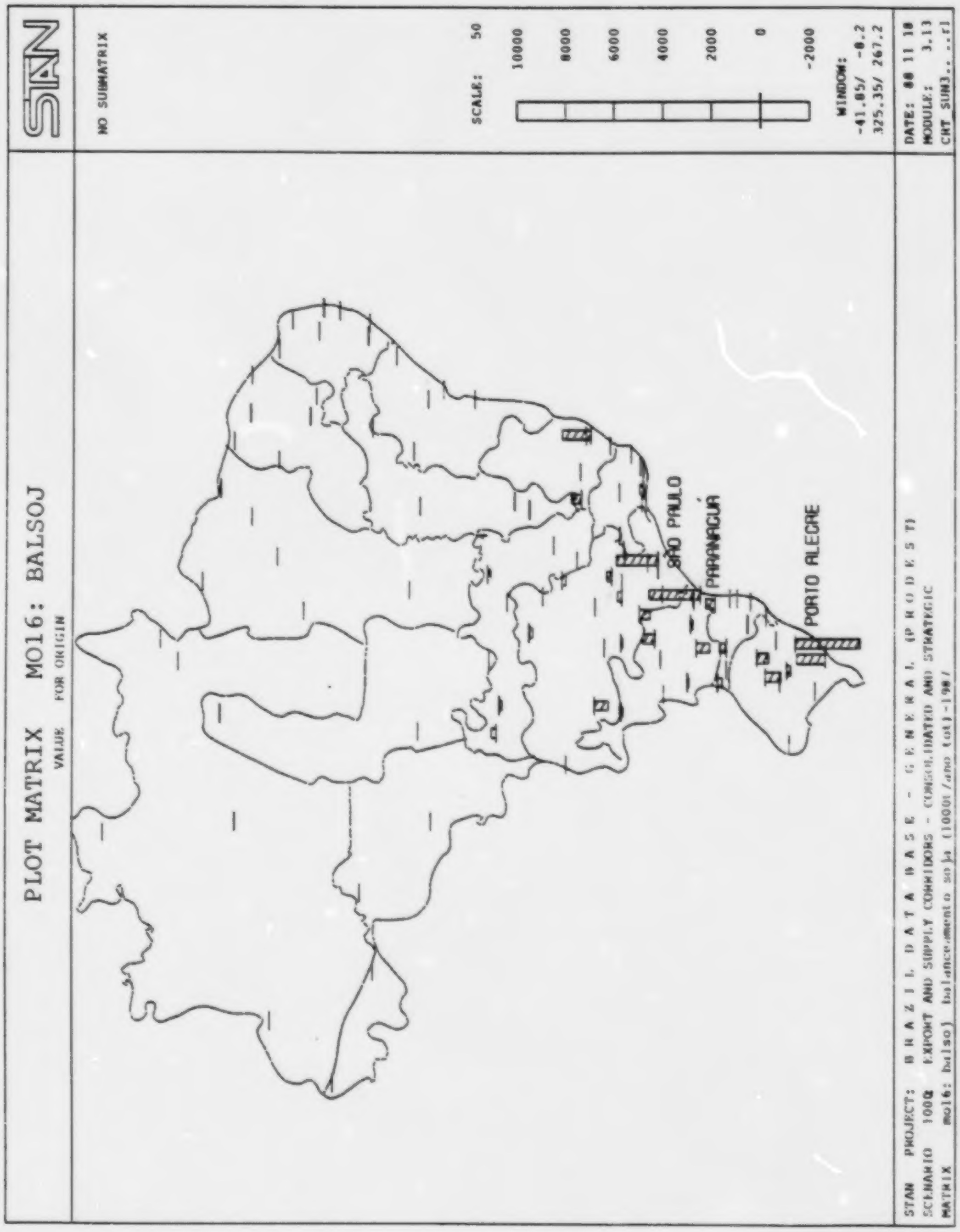

STAN
PLOT MATRIX M016: BALSOJ
VALUE FOR ORIGIN
NO SUBMATRIX
SCALE: 50
10000
8000
6000
4000
2000
0
-2000
WINDOW:
-41.05/ -0.2
325.35/ 267.2
SÃO PAULO
PARANAGUÁ
PORTO ALEGRE
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mo16: balsoj balanceamento soja (1000t/ano tot)-1987
DATE: 88 11 10
MODULE: 3.13
CMT SUN3.. ..fl

Figure 16 Soya Bean Demand Differences

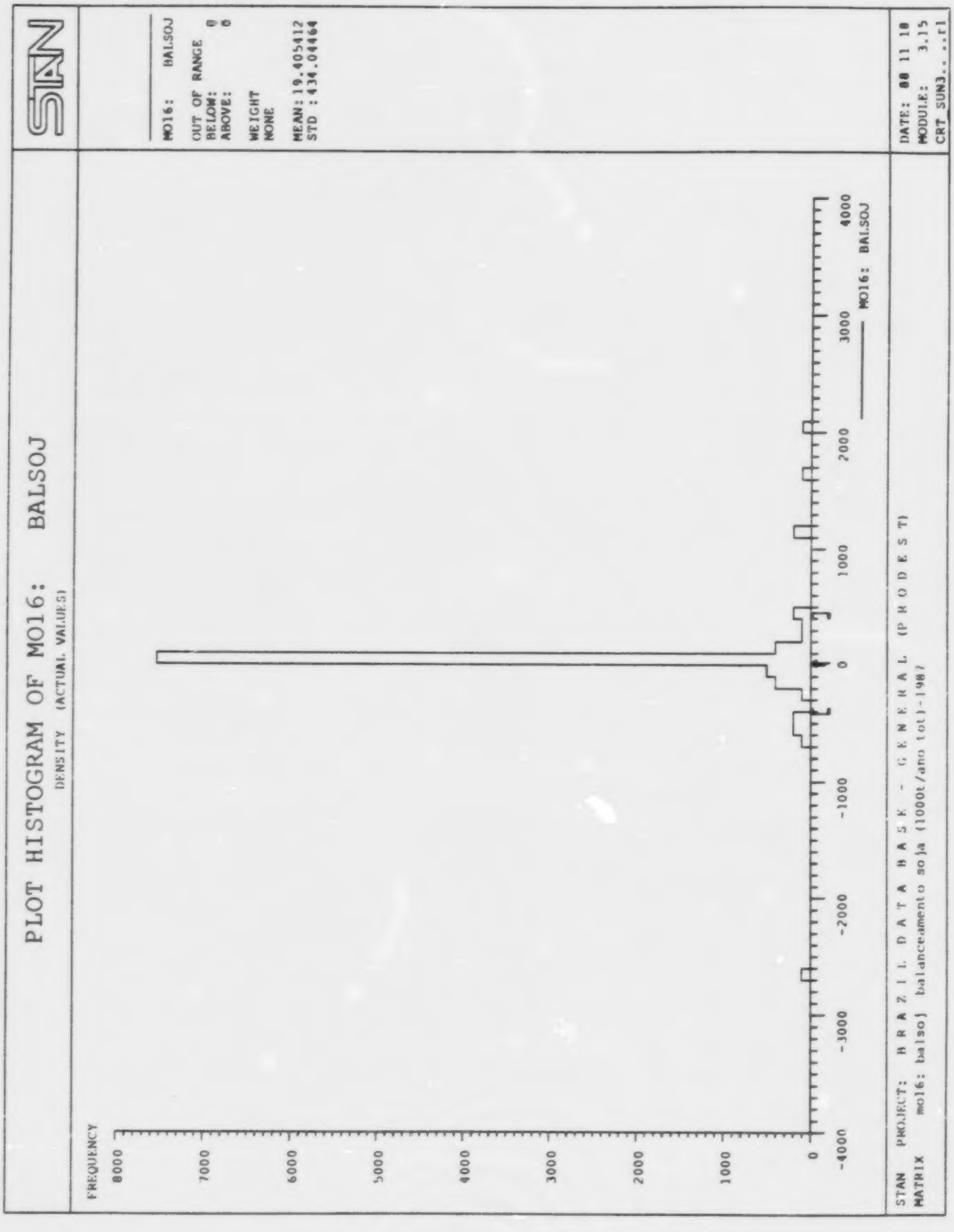


Figure 17 Histogram of Demand Differences

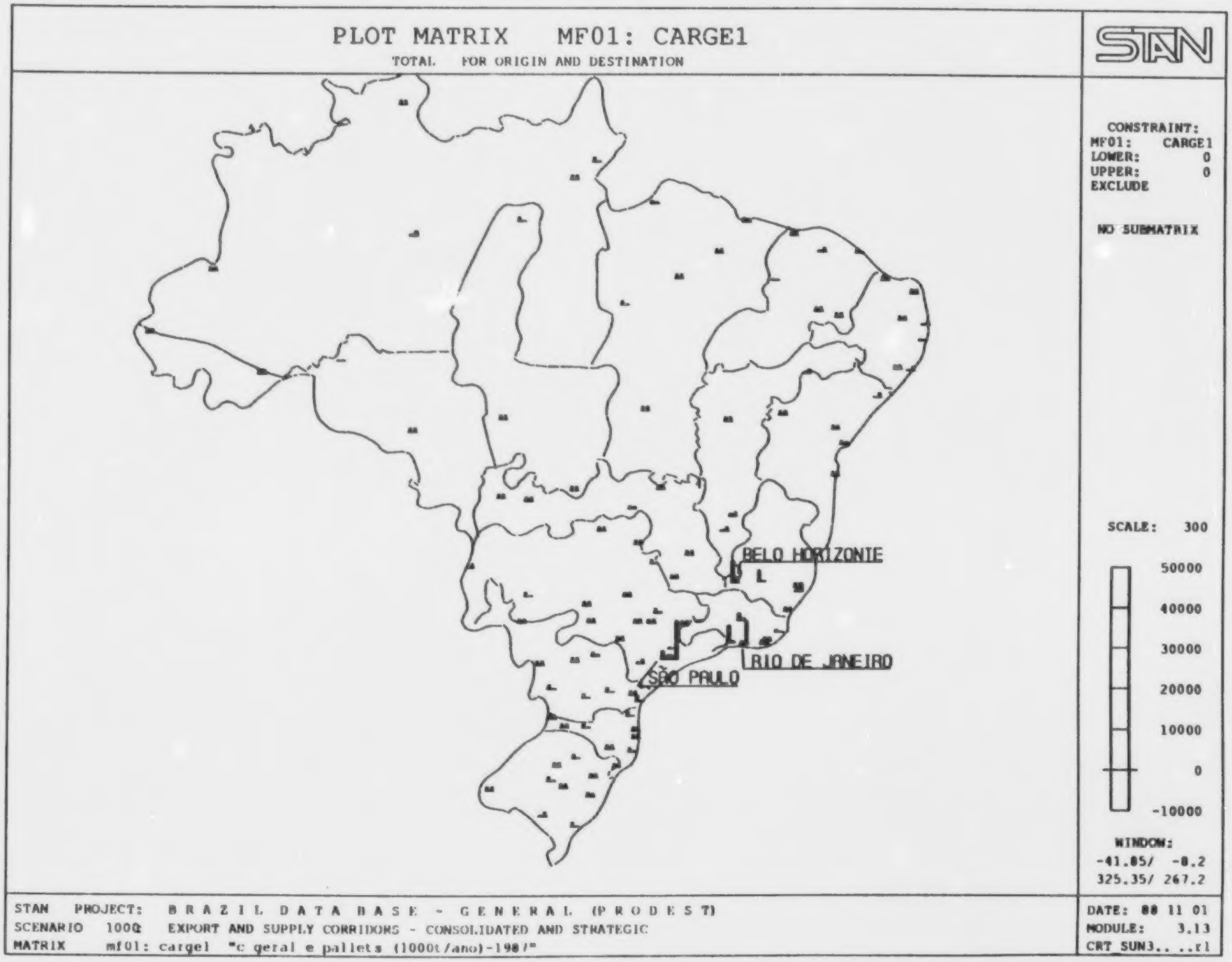

PLOT MATRIX MF01: CARGE1
TOTAL FOR ORIGIN AND DESTINATION
STAN
CONSTRAINT:
MF01: CARGE1
LOWER: 0
UPPER: 0
EXCLUDE
NO SUBMATRIX
BELO HORIZONTE
RIO DE JANEIRO
SÃO PAULO
SCALE: 300
50000
40000
30000
20000
10000
0
-10000
WINDOW:
-41.85/ -8.2
325.35/ 267.2
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mf01: cargel "c geral e pallets (1000t/ano)-1987"
DATE: 88 11 01
MODULE: 3.13
CRT_SUN3.. ..rl

Figure 18 General Cargo - Supply and Demand

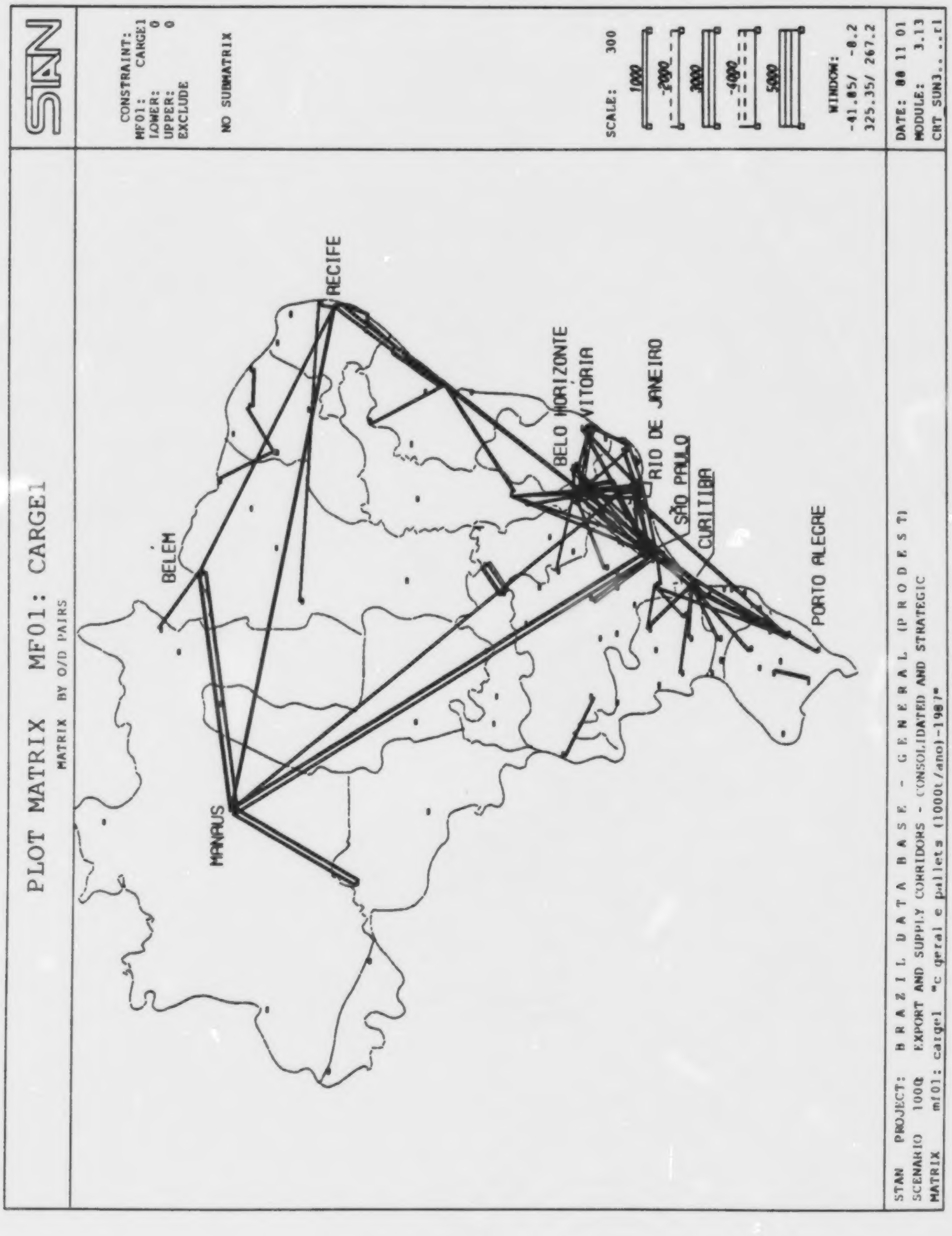

STAN
PLOT MATRIX MF01: CARGE1
MATRIX BY O/D PAIRS
CONSTRAINT:
MF01: CARGE1
LOWER: 0
UPPER: 0
EXCLUDE
NO SUBMATRIX
SCALE: 300
1000
2000
3000
4000
5000
WINDOW:
-41.85/ -8.2
325.35/ 267.2
BELEM
RECIFE
MANAUS
BELO HORIZONTE
VITORIA
RIO DE JANEIRO
SÃO PAULO
CURITIBA
PORTO ALEGRE
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mf01: carge1 "c geral e pallets (1000t/ano)-1987"
DATE: 88 11 01
MODULE: 3.13
CRT SUN3...rl

Figure 19 General Cargo - Desire Lines

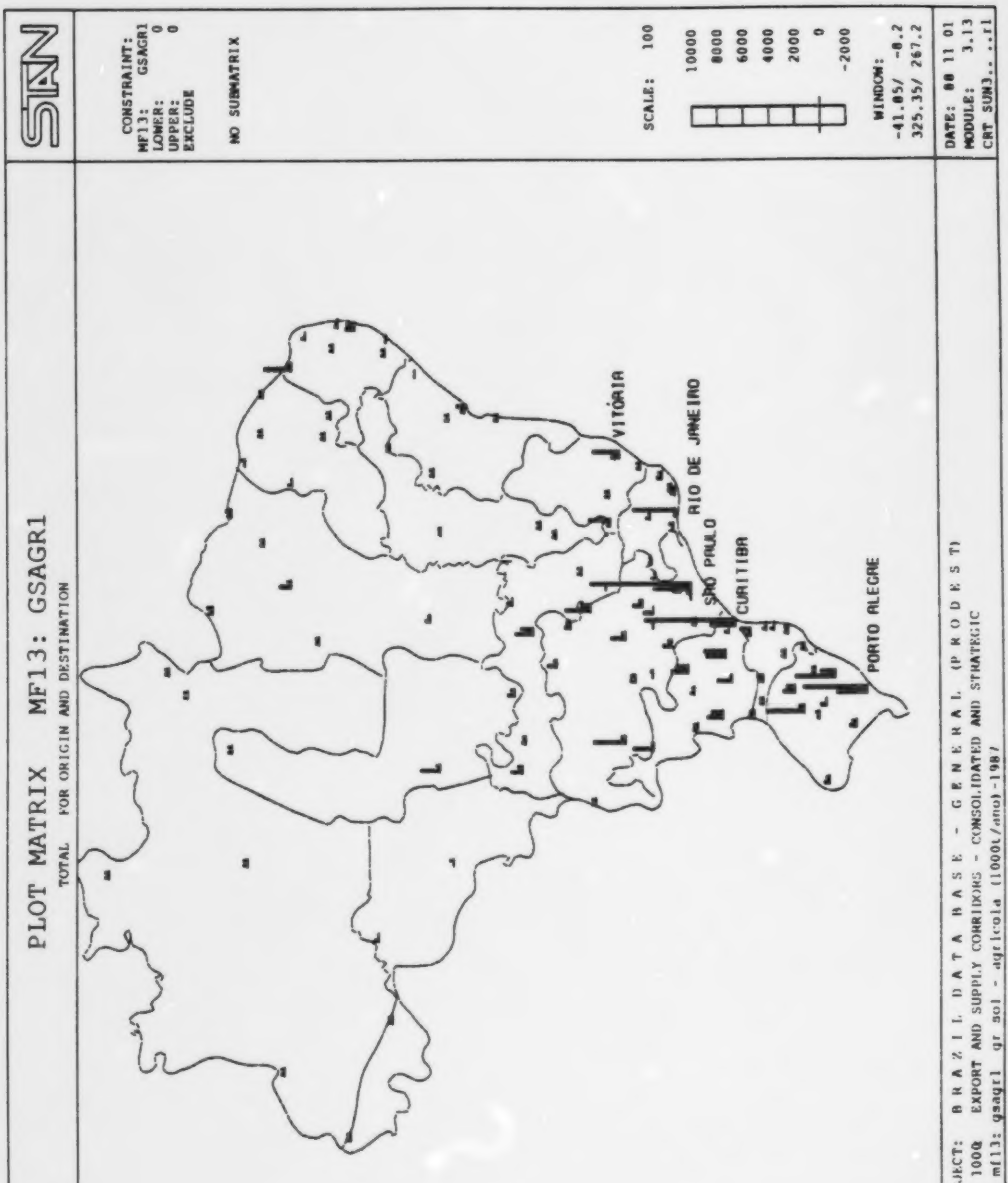

PLOT MATRIX MF13: GSAGR1
TOTAL FOR ORIGIN AND DESTINATION
STAN
CONSTRAINT:
MF13: GSAGR1
LOWER: 0
UPPER: 0
EXCLUDE
NO SUBMATRIX
SCALE: 100
10000
8000
6000
4000
2000
0
-2000
WINDOW:
-41.05/ -8.2
325.35/ 267.2
VITÓRIA
RIO DE JANEIRO
SÃO PAULO
CURITIBA
PORTO ALEGRE
STAN PROJECT: B R A Z I L D A T A B A S E - G E N E R A L (P R O D E S T)
SCENARIO 1000 EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mf13: gsagr1 gr sol - agricola (1000t/ano)-1987
DATE: 88 11 01
MODULE: 3.13
CRT SUN3.. ..rl

Figure 20 Agricultural Solid Bulk - Supply and Demand

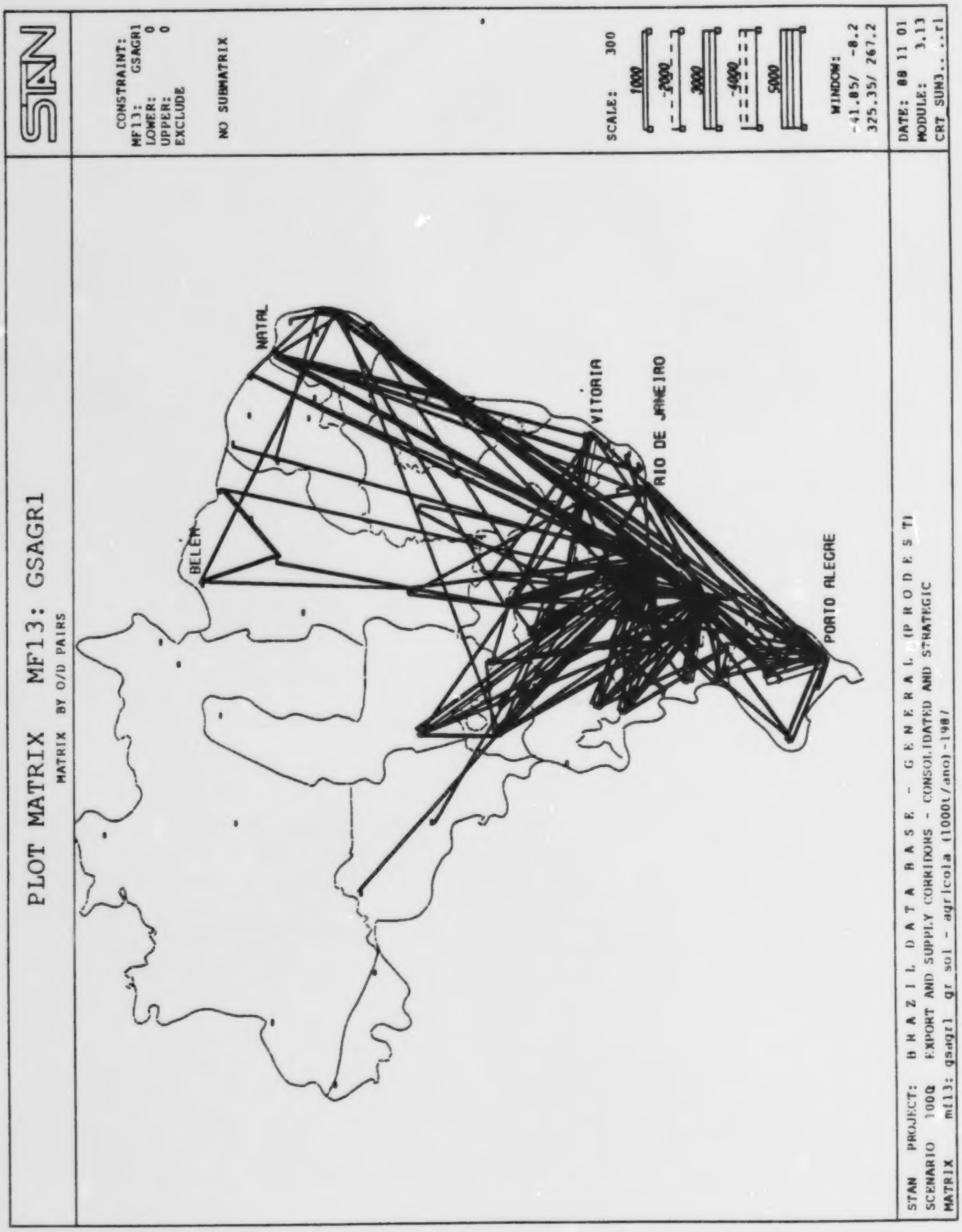

STAN
PLOT MATRIX MF13: GSAGR1
MATRIX BY O/D PAIRS
CONSTRAINT:
MF13: GSAGR1
LOWER: 0
UPPER: 0
EXCLUDE
NO SUBMATRIX
NATAL
BELEM
VITORIA
RIO DE JANEIRO
PORTO ALEGRE
SCALE: 300
1000
2000
3000
4000
5000
WINDOW:
-41.85/ -8.2
325.35/ 267.2
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mf13: gsagr1 gr sol - agricola (1000t/ano)-1987
DATE: 88 11 01
MODULE: 3.13
CRT SUN3....rl

Figure 21 Agricultural Solid Bulk - Desire Lines

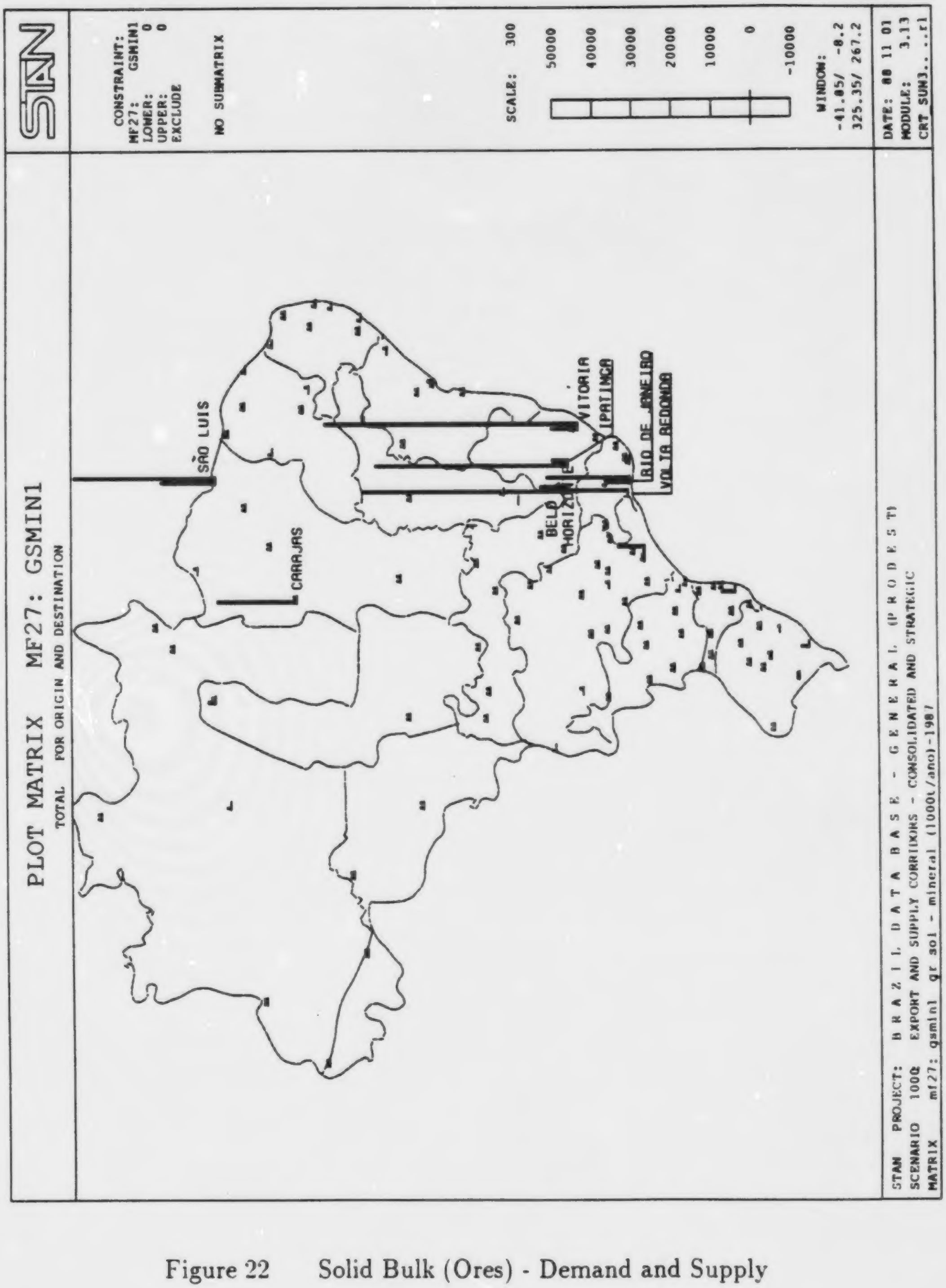

STAN
PLOT MATRIX MF27: GSMIN1
TOTAL FOR ORIGIN AND DESTINATION
CONSTRAINT:
MF27: GSMIN1
LOWER: 0
UPPER: 0
EXCLUDE
NO SUBMATRIX
SCALE: 300
50000
40000
30000
20000
10000
0
-10000
WINDOW:
-41.05/ -8.2
325.35/ 267.2
DATE: 88 11 01
MODULE: 3.13
CRT SUN3.. ..r1
SÃO LUIS
CARAJAS
BELO HORIZONTE
VITORIA
IPATINGA
RIO DE JANEIRO
VOLTA REDONDA
STAN PROJECT: B R A Z I L D A T A B A S E - G E N E R A L (P R O D E S T)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mf27: gsmin1 gr sol - mineral (1000t/ano)-1987

Figure 22 Solid Bulk (Ores) - Demand and Supply

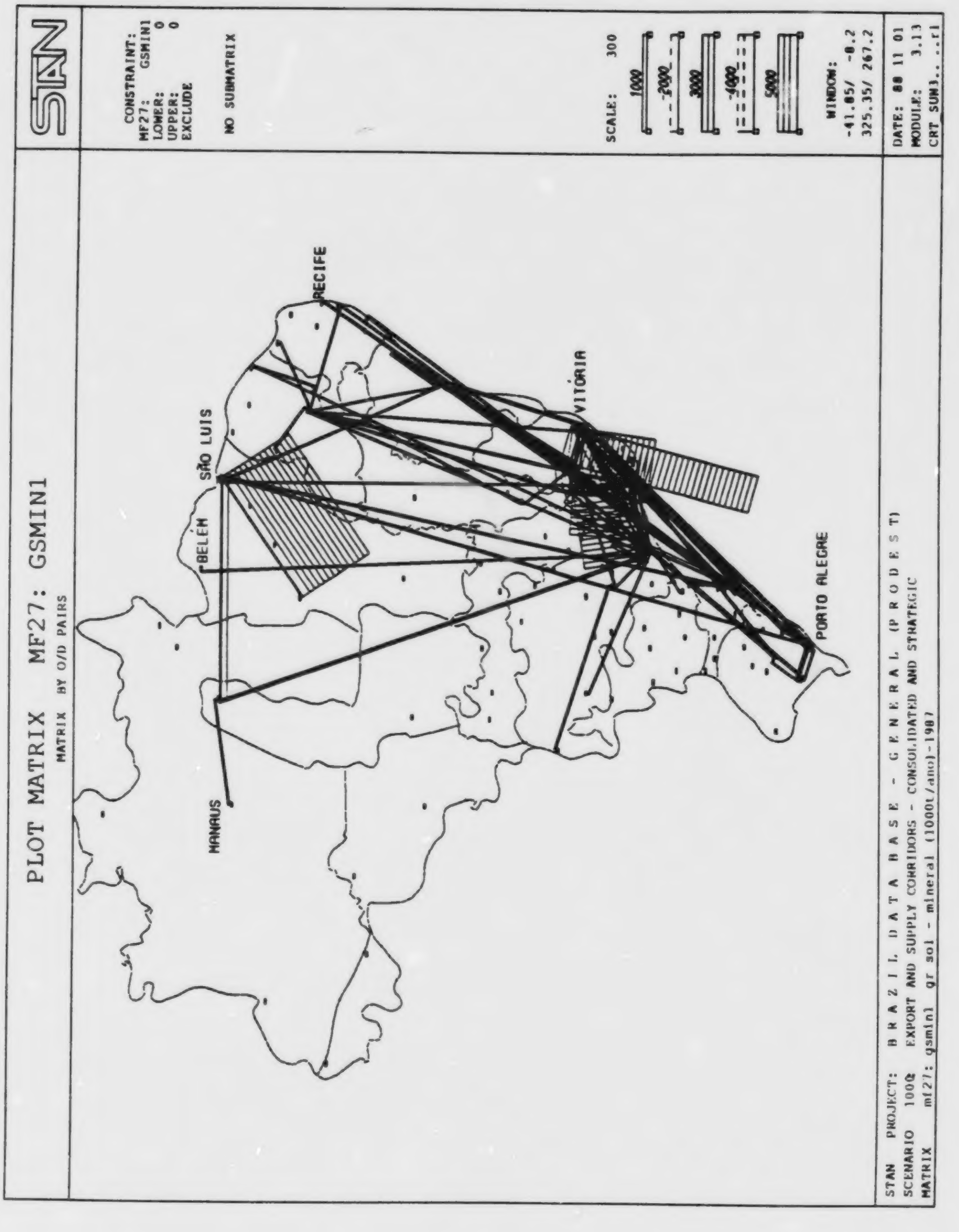

PLOT MATRIX MF27: GSMIN1
MATRIX BY O/D PAIRS
STAN
CONSTRAINT:
MF27: GSMIN1
LOWER: 0
UPPER: 0
EXCLUDE
NO SUBMATRIX
SCALE: 300
1000
2000
3000
4000
5000
WINDOW:
-41.85/ -8.2
325.35/ 267.2
DATE: 88 11 01
MODULE: 3.13
CRT SUN3.. ..r1
RECIFE
VITÓRIA
SÃO LUIS
BELÉM
MANAUS
PORTO ALEGRE
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mf27: gsmin1 gr sol - mineral (1000t/ano)-1987

Figure 23 Solid Bulk (Ores) - Desire Lines

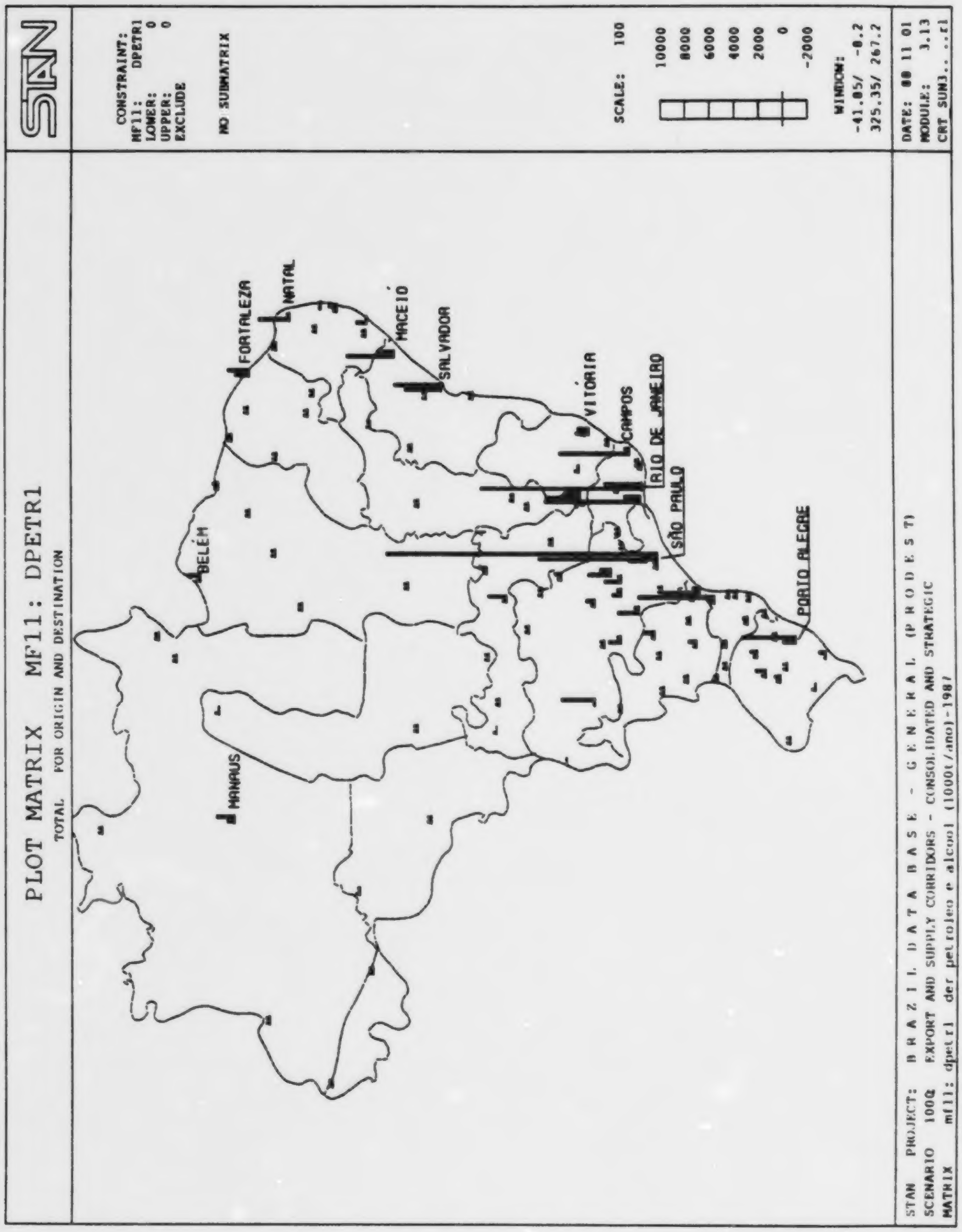
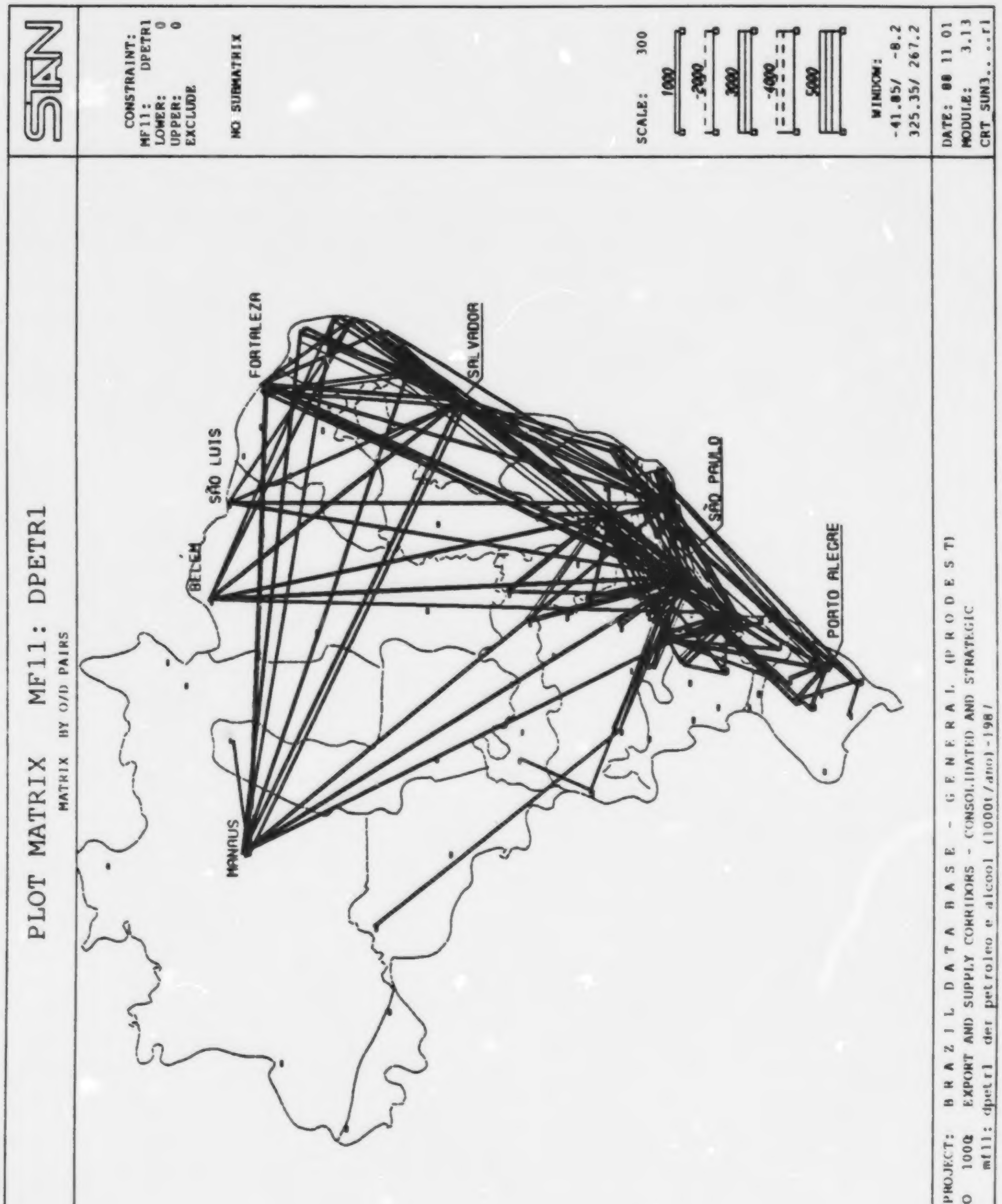

PLOT MATRIX MF11: DPETR1
TOTAL FOR ORIGIN AND DESTINATION
STAN
CONSTRAINT:
MF11: DPETR1
LOWER: 0
UPPER: 0
EXCLUDE
NO SUBMATRIX
SCALE: 100
10000
8000
6000
4000
2000
0
-2000
WINDOW:
-41.05/ -0.2
325.35/ 267.2
DATE: 88 11 01
MODULE: 3.13
CRT SUN3.. ..f1
FORTALEZA
NATAL
MACEIÓ
SALVADOR
VITÓRIA
CAMPOS
RIO DE JANEIRO
SÃO PAULO
PORTO ALEGRE
BELÉM
MANAUS
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mf11: dpetr1 der petroleo e alcool (1000t/ano)-1987

Figure 24 Petroleum and Byproducts - Supply and Demand


PLOT MATRIX MF11: DPETR1
MATRIX BY O/D PAIRS
STAN
CONSTRAINT:
MF11: DPETR1
LOWER: 0
UPPER: 0
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SCALE: 300
1000
2000
3000
4000
5000
WINDOW:
-41.05/ -8.2
325.35/ 267.2
DATE: 08 11 01
MODULE: 3.13
CRT SUN3.. ..r1
FORTALEZA
SALVADOR
SÃO LUIS
BELÉM
SÃO PAULO
PORTO ALEGRE
MANAUS
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mf11: dpetr1 der petroleo e alcool (1000t/ano)-1987

Figure 25 Petroleum and Byproducts - Desire Lines

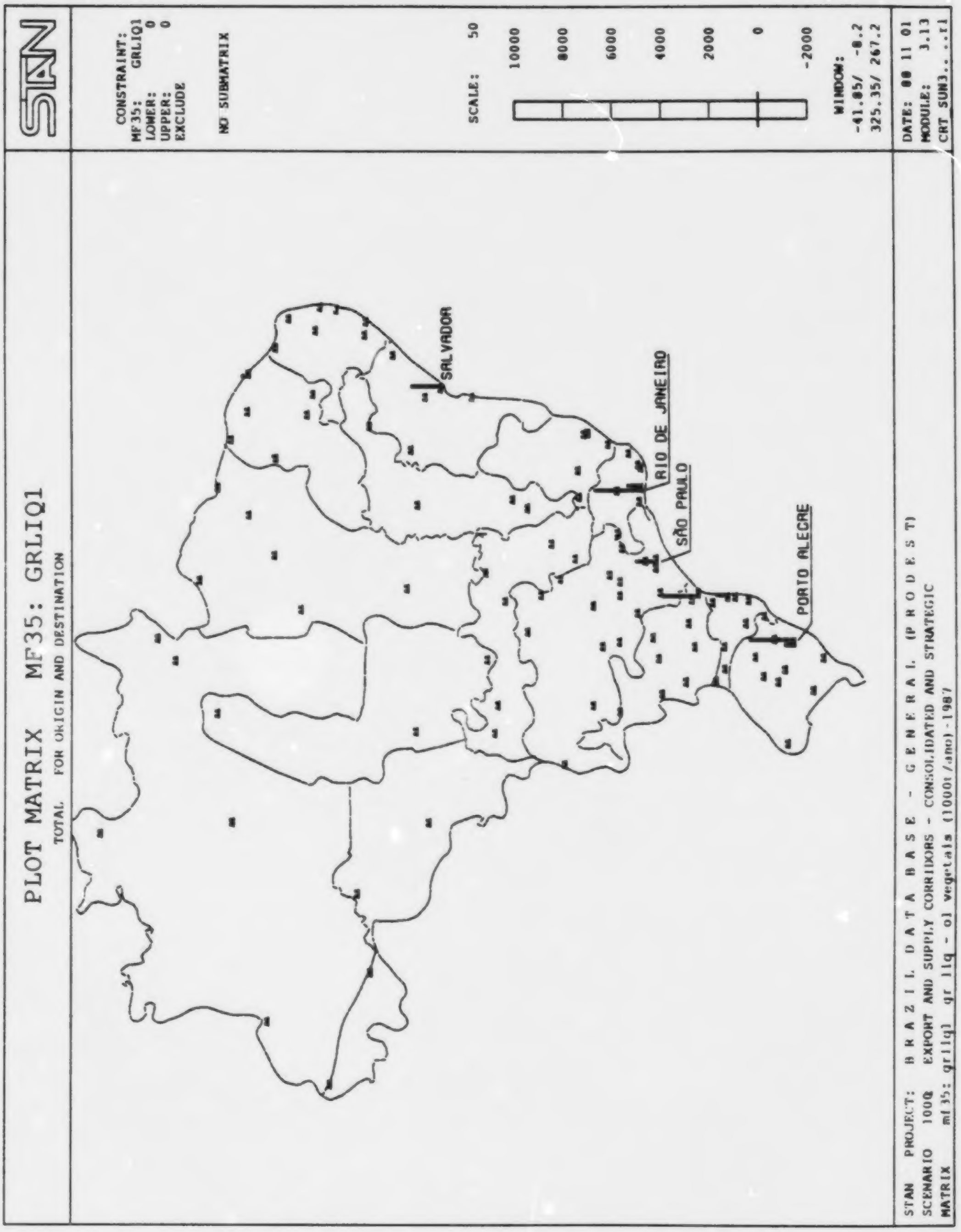
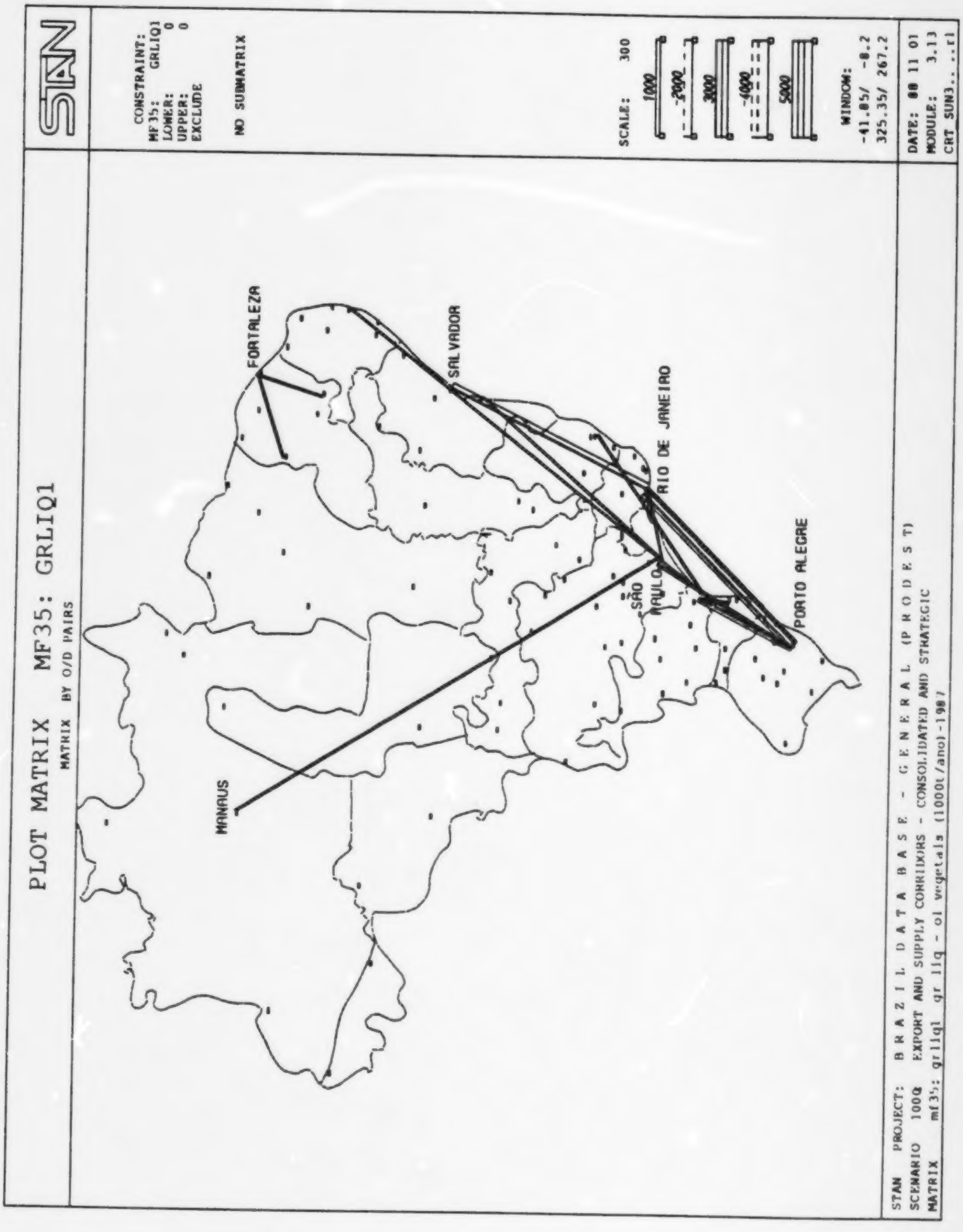

STAN
PLOT MATRIX MF35: GRLIQ1
TOTAL FOR ORIGIN AND DESTINATION
CONSTRAINT:
MF35: GRLIQ1
LOWER: 0
UPPER: 0
EXCLUDE
NO SUBMATRIX
SCALE: 50
10000
8000
6000
4000
2000
0
-2000
WINDOW:
-41.85/ -8.2
325.35/ 267.2
DATE: 88 11 01
MODULE: 3.13
CRT SUN3...
SALVADOR
RIO DE JANEIRO
SÃO PAULO
PORTO ALEGRE
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mf35: grliq1 gr liq - ol vegetais (1000t/ano)-1987

Figure 26 Liquid Bulk - Supply and Demand


PLOT MATRIX MF35: GRLIQ1
MATRIX BY O/D PAIRS
STAN
CONSTRAINT:
MF35: GRLIQ1
LOWER: 0
UPPER: 0
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SCALE: 300
1000
2000
3000
4000
5000
WINDOW:
-41.85/ -8.2
325.35/ 267.2
DATE: 88 11 01
MODULE: 3.13
CRT SUN3... ..rl
FORTALEZA
SALVADOR
RIO DE JANEIRO
SÃO PAULO
PORTO ALEGRE
MANAUS
STAN PROJECT: BRAZIL DATA BASE - GENERAL (PRODEST)
SCENARIO 100Q EXPORT AND SUPPLY CORRIDORS - CONSOLIDATED AND STRATEGIC
MATRIX mf35: grliq1 gr liq - ol vegetais (1000t/ano)-1987

Figure 27 Liquid Bulk - Desire Lines

CHAPTER THREE

THE SÃO FRANCISCO RIVER CORRIDOR APPLICATION

In the Strategic Corridors Program, the São Francisco river constitutes an important axis for the transportation system, that fulfills the goal of integrating new productive spaces into the national economy, and as an alternate connection between the Northeast and Center-South regions of Brazil.

The São Francisco waterway already represented in the past, during a long period of the Brazilian history, the major, and sometimes the only, connection between the villages and farms in the west of the states of Bahia and Minas Gerais and the coastline of Brazil. The river was mostly used for transportation during the 1920-1930 decade, due to the expansion of activities of the different shipowners and due to the growth of governmental companies. Since 1869, the ships that navigate the river use mechanical power.

The implementation and development of the railway and, principally, the highway systems reduced the relative importance of transportation on the São Francisco river. The promotion of modal integration was not a major concern at that time. During the 1960-1970 decade, the government showed again an interest in water transportation through the São Francisco valley, due to various reasons: the development of agricultural and cattle raising programs implemented by the Company for the Development of the São Francisco Valley (CODEVASF), the exploration of ores by the Northeast Development Agency (SUDENE), and in view of the impending oil crisis. The availability of electrical power and the merger of several companies into a state navigation company (FRANAVE) also provided favorable conditions for such a development. Several studies, including a number of GEIPOT projects, were carried out, aimed at the improvement of the navigation on the São Francisco river and of the associated port operations.

During the 1974-1980 period, navigation on the river was impaired by the construction of the dam and lock of Sobradinho, located 40 km upstream of Juazeiro/-Petrolina. Navigation was interrupted on the section from Sobradinho to Juazeiro/-Petrolina, which made waterway transportation difficult between the major centers. On the other hand, navigation conditions on the lake created by the damming of Sobradinho were found to be very different from those on the rest of the river, requiring substantial adaptations in the boats used in the region.

The inception of the Strategic Corridors Program and, more recently, the development of the Transportation Sector according to the concept of transportation corridors (PRODEST, 1987/90), finally introduced a systemic approach to the planning of cargo movement in the São Francisco Valley, including the multimodal consideration of the transportation means, storage facilities and the inter- and intra-sectorial transshipment facilities. The application of STAN was used in the Study for Making the São Francisco River Corridor Operational, which aimed to propose investments and actions on a set of means destined principally to attract the production of goods generated within the area of influence of the river.

In the context of strategic planning, the analyses performed by using the STAN system permitted to determine the distribution of freight flows and the utilization of the transportation system, which are essential factors for the analysis of investments and actions toward improving the navigation on the São Francisco river. In addition to the traffic transiting through the region, it is estimated that the production potential in the area may reach 13 million tons of agricultural products, thus requiring the consolidation of the transportation axes. On the other hand, this consolidation may be achieved only within a multimodal environment, which, other than the investiments for the waterway mode, also emphasizes the construction of the Ferrovia Sertaneja or Transnordestina (Transnortheastern Railway) which is aimed to integrating the railway network in the Northeast. Consequently, various transportation supply and demand scenarios were constructed and their analysis with the STAN system resulted in important contributions to the study.

3.1 CHARACTERIZATION OF THE STUDY AREA

3.1.1 Socioeconomic Aspects

The definition of the study area of the São Francisco river corridor identified two levels of influence of the river transportation, which is the principal penetration axis. The first level corresponds to the direct area of influence and is made up of the region boarding the river and covering parts of the states of Bahia, Minas Gerais, Pernambuco, Ceará and Piauí, as apparent when superposing Figures 1 and 2.

The delimitation of this area of direct influence was carried out according to criteria of economic concentration, transportation flows and the configuration of the transportation network in the region. Therefore, a 700 000 km^2 area surrounding the river section between Pirapora and Petrolina/Juazeiro, capable of generating flows for this river section, was considered. It is important to note that this area coincides with that of previous GEIPOT studies and with the PRODEST (1987/90) characterization of the São Francisco river corridor, since the evolution of the aspects considered in its definition was not significant enough to justify changes in its delimitations.

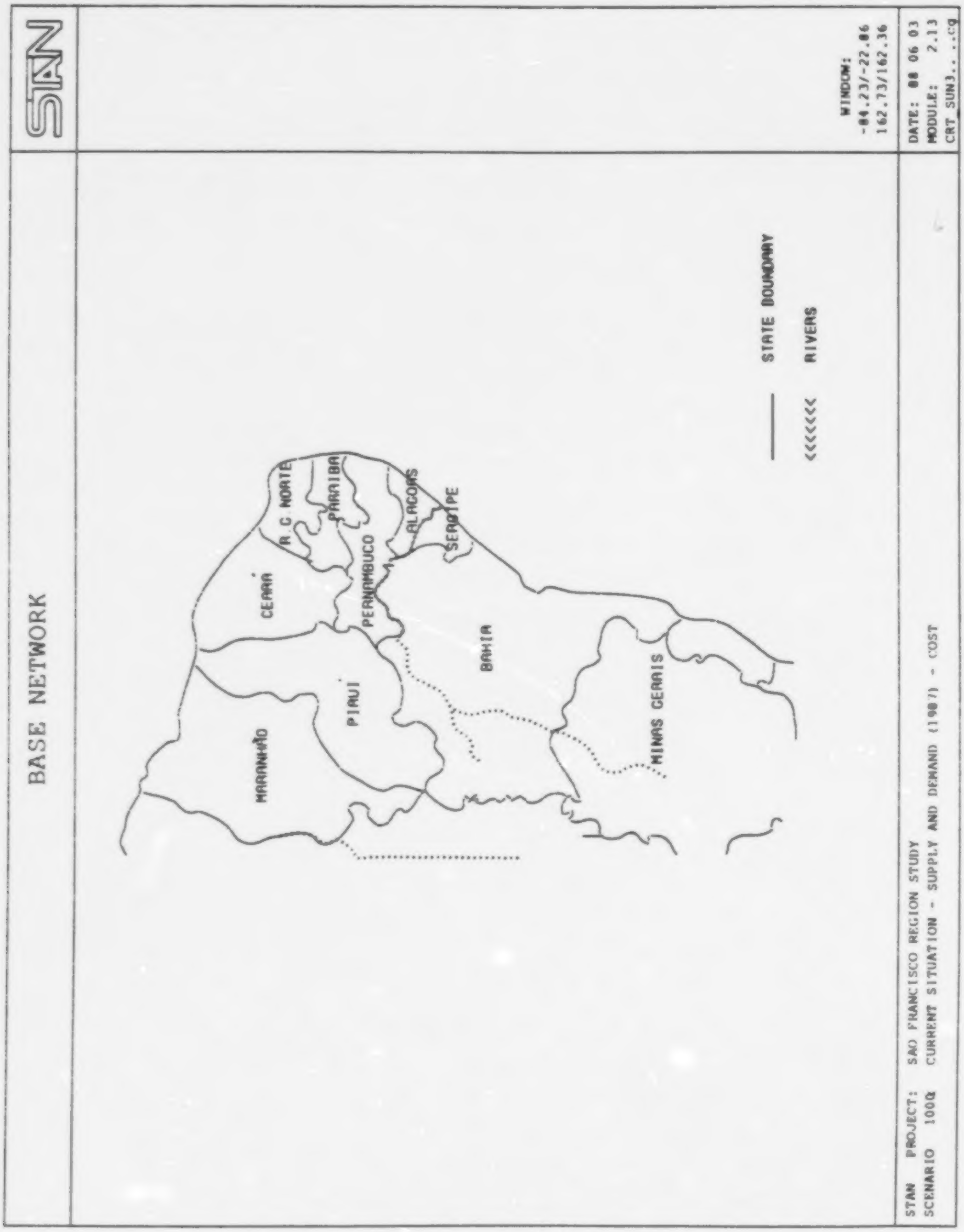

BASE NETWORK
STAN
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 03
MODULE: 2.13
CRT SUN3....cg
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100Q CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST
STATE BOUNDARY
RIVERS
R.C. NORTE
PARAIBA
ALAGOAS
SERGIPE
PERNAMBUCO
CEARÁ
BAHIA
PIAUÍ
MARANHÃO
MINAS GERAIS

Figure 1 States in the Influence Area of the São Francisco River Corridor

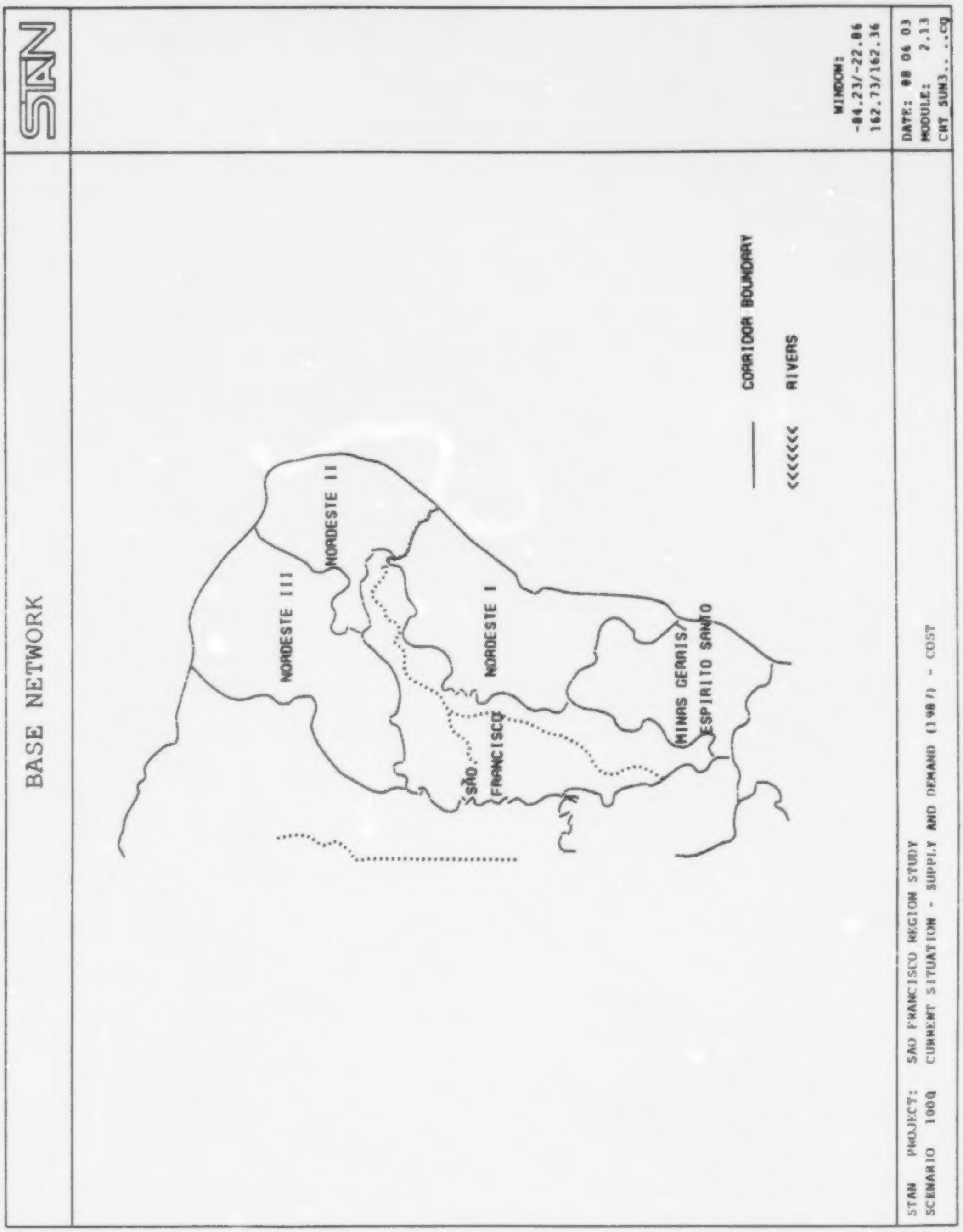

STAN
BASE NETWORK
WINDOW:
-04.23/-22.06
162.73/162.36
DATE: 88 06 03
MODULE: 2.13
CHT SUN3.. ..cg
NORDESTE II
NORDESTE III
NORDESTE I
MINAS GERAIS/
ESPIRITO SANTO
SÃO
FRANCISCO
CORRIDOR BOUNDARY
RIVERS
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100Q CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST

Figure 2 Transportation Corridors in the North-East

At the second level, the area of indirect influence was defined as the one generating long-distance traffic with a potential for using the transportation system of the São Francisco river. This is the traffic between the North/Northeast and Southeast regions. These large regions were considered in the study by simplifying their transportation networks according to the National Basic Transportation System (SNBT).

The valley of the São Francisco river, is a very important strategic area in the national integration effort, due to its potential resources and geographical location. The major economic activities in this area are still associated with the primary sector: an agriculture mostly of subsistence and cattle raising activities with low productivity indices. Mineral exploitation of gypsum and magnesite is the major activity of the secondary sector. Transformation industries are insignificant. The population of the valley is very scattered (6.8 inhabitants/km^2) which, together with its participation of only 9% of the total income generated in the Northeast, identifies it as an area of economic expansion in the Strategic Corridors Program.

Although clearly displaying characteristics of an underdeveloped region, the area of influence of the waterway section presents good development prospects for the next decades. Presently, an accelerated process of expansion of the agricultural frontier is occuring, that mobilizes the public and private sectors and which will increase the transportation demand generated by the region. The irrigation program of CODEVASF, for example, is expected to raise the agricultural production (rice, corn, soyabean and bean) to 14.9 million tons by 1990. Due to the development of the sugarcane production, there are also a number of projects for the implementation of distilleries, in which case alcohol will be another product generating transportation demand.

Five products, relevant for the utilization of the transportation system in the region, were consequently selected for use in the application of the STAN system. These were: agricultural solid bulk (including bean, corn, soyabean and rice), gypsum, salt, cement and petroleum byproducts (including alcohol). The last three were considered principally as transit flows, that will be passing through the transportation system in the region. When considering all development prospects, these products are estimated to represent more than 80% of the freight transportation in the valley of the São Francisco river. The year 1987 was defined as the base year in this application, with the year 1990 as a projection horizon, in accordance with the period covered by PRODEST. Also, the accelerated development process in the region makes demand forecasts for a period of over five years very precarious.

3.1.2 The Transportation Network

The transportation system of the São Francisco Corridor connects, at its extremities, the navigable section of the river between Petrolina/Juazeiro and Pirapora with feeder roads and railway networks. Considering the area of indirect influence, the alternative and complementary highway and railway infrastructure was also included in the model, in order to connect the major economic centers and ports in the Northeast and Center-South regions. Coastal navigation was also included. Consequently, the transportation network included in the study, represented in Figure 3, covers a total extent of about 55 000 km, a significant part of which lies outside the corridor.

The navigable section of the São Francisco river is 1700 km long, with a maximum operating draft of 1.20 m, whose maintenance depends on the operation of the Sobradinho and Três Marias dams (see Figure 4). Of its triburaries, only the Grande and the Corrent rivers represent commercial interest and display characteristics similar to those of the São Francisco. The river ports of the region may be classified into

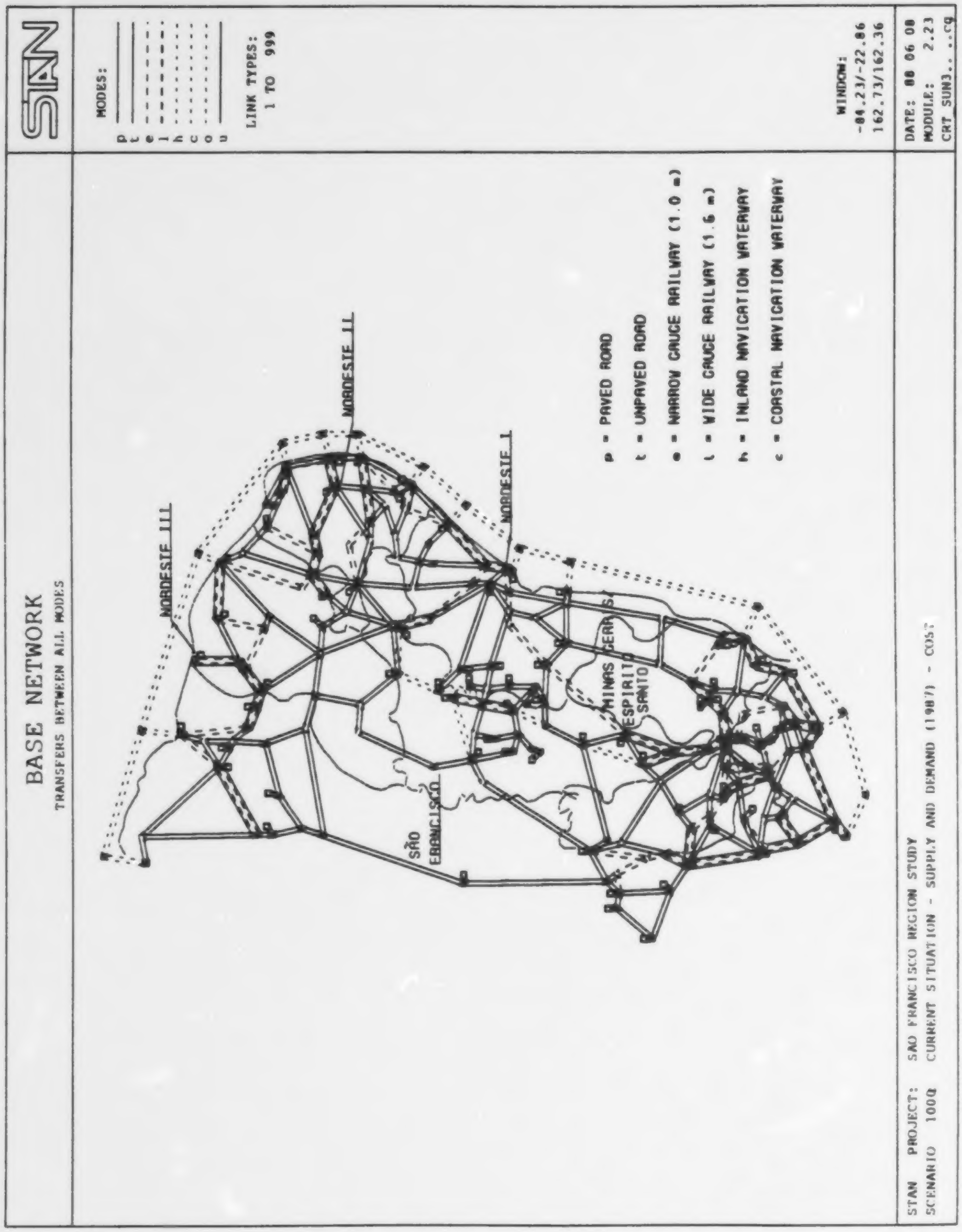

STAN
BASE NETWORK
TRANSFERS BETWEEN ALL MODES
MODES:
p
t
e
l
h
c
o
u
LINK TYPES:
1 TO 999
NORDESTE III
NORDESTE II
NORDESTE I
SÃO FRANCISCO
MINAS GERAIS
ESPIRITO SANTO
p = PAVED ROAD
t = UNPAVED ROAD
e = NARROW GAUGE RAILWAY (1.0 m)
l = WIDE GAUGE RAILWAY (1.6 m)
h = INLAND NAVIGATION WATERWAY
c = COASTAL NAVIGATION WATERWAY
WINDOW:
-84.23/-22.86
162.73/162.36
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100Q CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST
DATE: 88 06 08
MODULE: 2.23
CRT SUN3.. ..CG

Figure 3 The Transportation Network

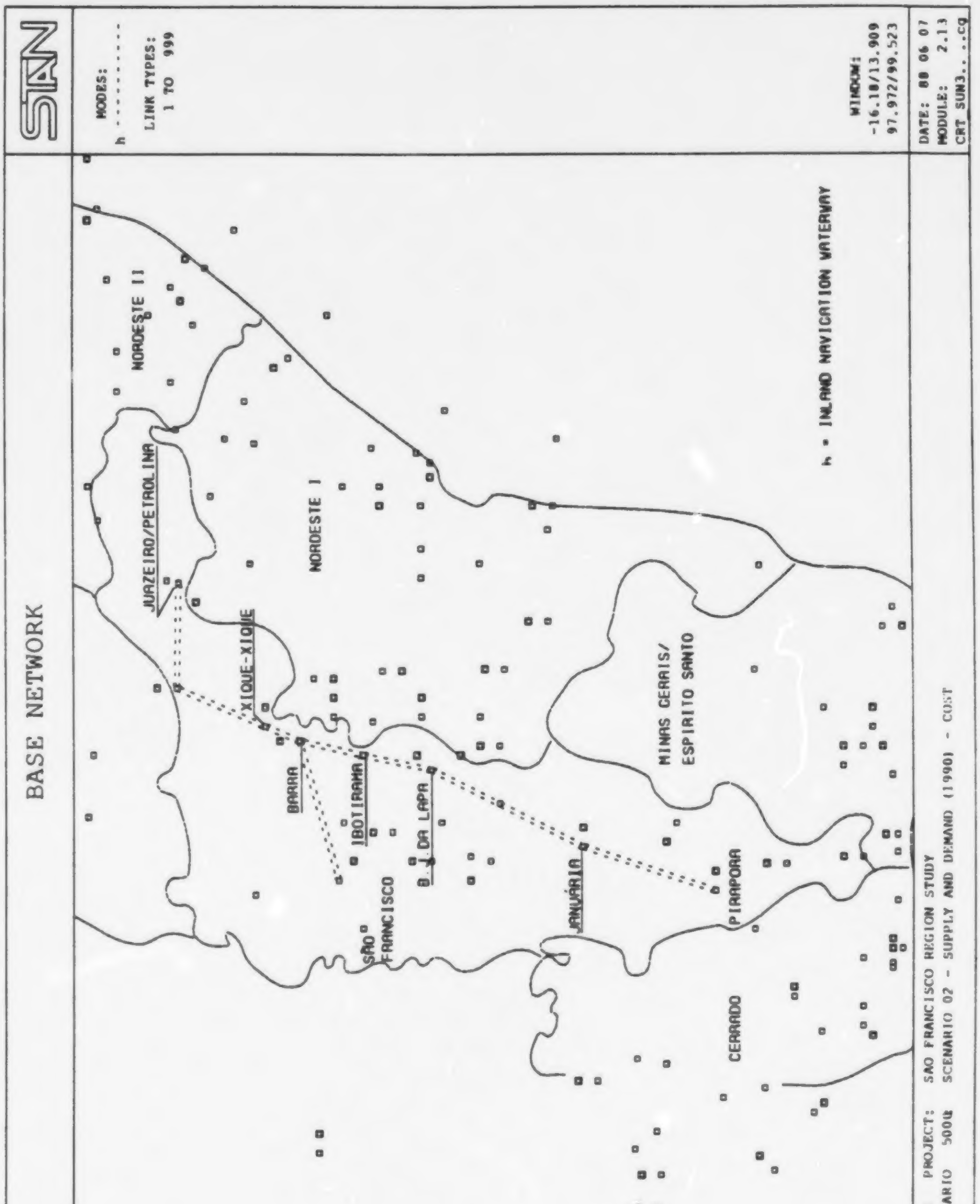

STAN
MODES:
h ----------
LINK TYPES:
1 TO 999
WINDOW:
-16.18/13.909
97.972/99.523
DATE: 88 06 07
MODULE: 2.13
CRT SUN3... ..cg
BASE NETWORK
NORDESTE II
NORDESTE I
JUAZEIRO/PETROLINA
XIQUE-XIQUE
BARRA
IBOTIRAMA
B.J.DA LAPA
JANUÁRIA
PIRAPORA
SÃO FRANCISCO
MINAS GERAIS/
ESPIRITO SANTO
CERRADO
h = INLAND NAVIGATION WATERWAY
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 500Q SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST

Figure 4 The Navigable Section of the São Francisco River

three categories, according to their docking facilities: adequate (Juazeiro/Petrolina and Pirapora), rudimentary (Xique-Xique, Barra, Ibotirama, Bom Jesus da Lapa and Januária) and ports using the river banks directly. The latter were not considered in the study. In addition to the need for a permanent river delimitation and port facilities, the low performance of the navigation mode is largely due to lack of entrepreneurship for cargo attraction and precarious boat maintenance practices.

Two types of roads were identified: those used for local transportation and those used for long distance transportation, with a total length of 34 000 km, including paved and unpaved roads (see Figure 5). This division facilitated the definition of the relevant modal network for the study, since most of the local roads or those in the area of direct influence are feeder roads to the navigation system. The long-distance roads are sometimes competitive with the navigation mode, in some cases they are complementary to waterway ports. The study identified a lack of capacity to meet the predicted growth in transportation demand, principally in the complementary and feeder system.

The railway system serving the middle São Francisco region is part of the RFFSA network and is composed of lines of the Regional Superintendency of Belo Horizonte (SR-2) between the cities of Belo Horizonte and Monte Azul and the Pirapora branch line, as well as of sections under the jurisdiction of the Regional Superintendency of Salvador (SR-7): the central line (Salvador-Juazeiro) and south line (Mapele-Monte Azul). In the area of direct influence there are therefore only two points of contact with the São Francisco river, namely Petrolina/Juazeiro and Pirapora. This characterizes rail as an alternative system. Other components of the railway network, that serve the extra-regional flows, are the lines of the Production Superintendency of Fortaleza (SP-1.1) and Recife (SP.1.2) in the Northeast, and those of the Regional Superintendency of Juiz de Fora (SR-3), FEPASA and EFVM in the Southeast (see

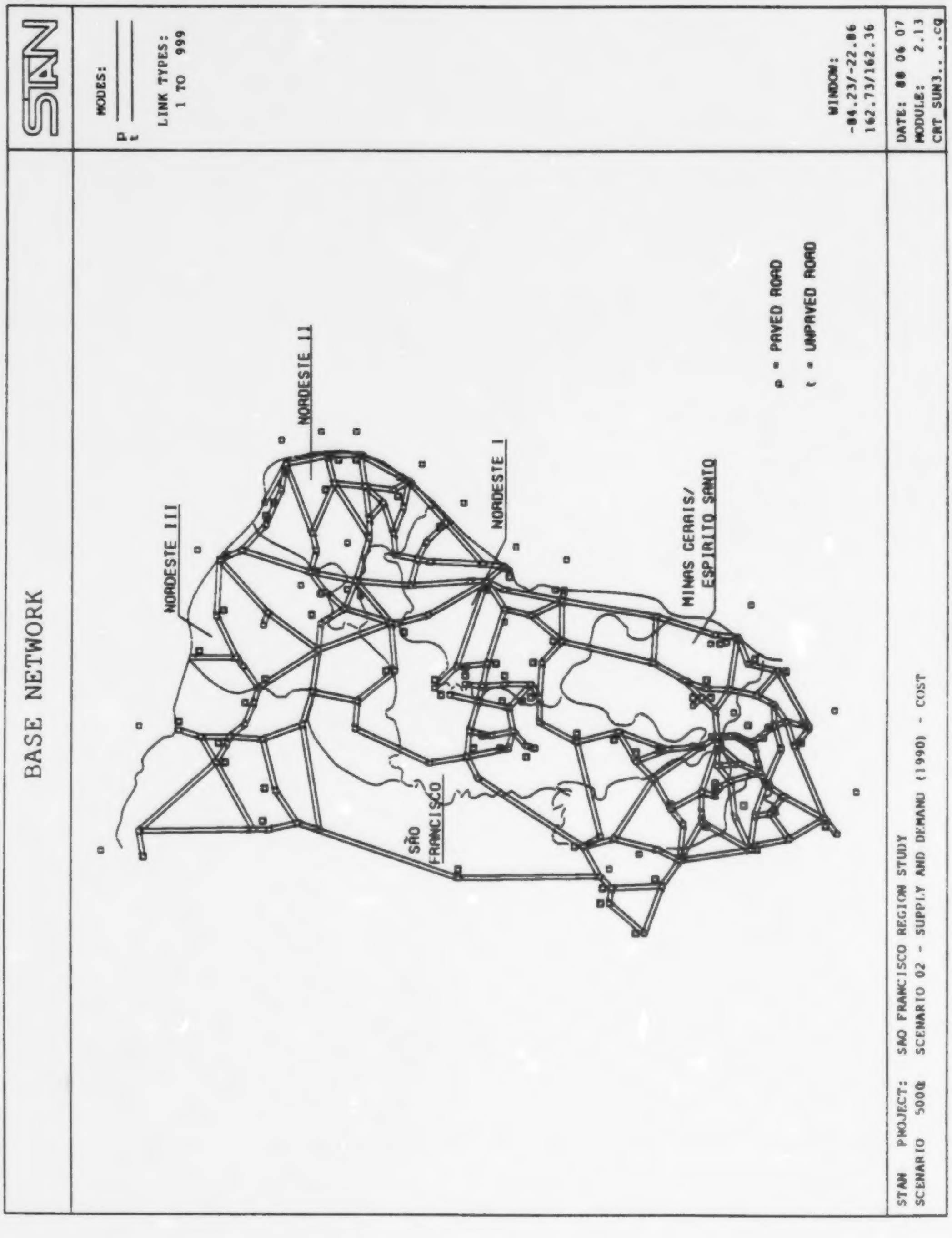

BASE NETWORK
STAN
MODES:
p
t
LINK TYPES:
1 TO 999
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 07
MODULE: 2.13
CRT SUN3.....cq
NORDESTE III
NORDESTE II
NORDESTE I
MINAS GERAIS/
ESPIRITO SANTO
SÃO
FRANCISCO
p = PAVED ROAD
t = UNPAVED ROAD
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 500Q SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST

Figure 5 The Road System

Figure 6), with a total length of 13 400 km. The construction of 450 km of the "Sertaneja" railway is vital to the adequacy of the rail mode to transport the predicted cargoes, since it integrates the Northeast railway network, via the connection between the cities of Petrolina and Salgueiro with a point of the branch line Arrojado-Crato (see Figure 7).

Coastal navigation between the major ports on the route Belém-Santos, with a total length 5 000 km, was also considered in the model (see Figure 6). Although competitive when compared to the inland transportation modes, coastal navigation, similarly to the São Francisco river navigation, has to be complemented the highway and railway networks in order to reach the final origins and destinations. For this mode, access links to maritime ports were also defined, in order to facilitate the graphical representation of the network.

Table 1 shows a summary of the number (unidirectional) and lengths of the links in the network for each mode. The figures in parentheses correspond to the inclusion of the Transnortheastern railway into the network. Different modes are defined for paved and unpaved roads and for wide and narrow gauge railways. Nodes were associated to the transportation demand location, to transshipment points and to points where changes in the physical characteristics of the sections occur. Links were defined between the appropriate nodes for each mode, so as to allow the representation of alternative routes in the transportation network and provide a realistic graphical representation of the transportation infrastructure. The representation of the location of origins and destinations by means of centroids, mares it necessary to define links to connect them to the transportation network. The mode associated with these links was named "single", noted (u), thus reflecting the freight collection in the traffic zone. The average inter-zonal distance was associated with the connetor links.

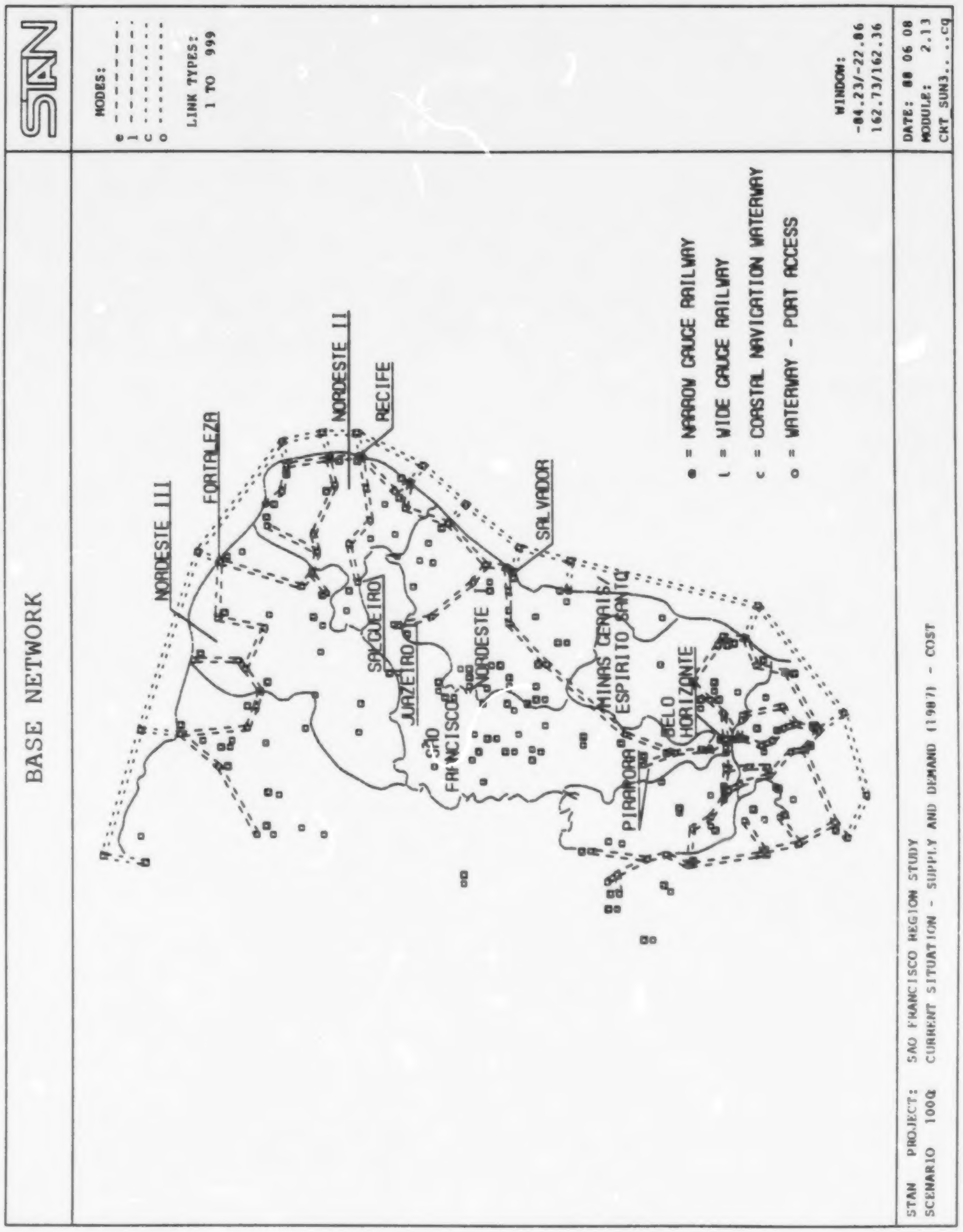

BASE NETWORK
STAN
MODES:
e
l
c
o
LINK TYPES:
1 TO 999
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 08
MODULE: 2.13
CRT SUN3.. ..Cg
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 1000 CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST
e = NARROW GAUGE RAILWAY
l = WIDE GAUGE RAILWAY
c = COASTAL NAVIGATION WATERWAY
o = WATERWAY - PORT ACCESS
NORDESTE III
FORTALEZA
NORDESTE II
RECIFE
SALVADOR
SALGUEIRO
JUAZEIRO
NORDESTE I
SAO FRANCISCO
MINAS GERAIS/ ESPIRITO SANTO
BELO HORIZONTE
PIRAPORA

Figure 6 Rail and Coastal Navigation

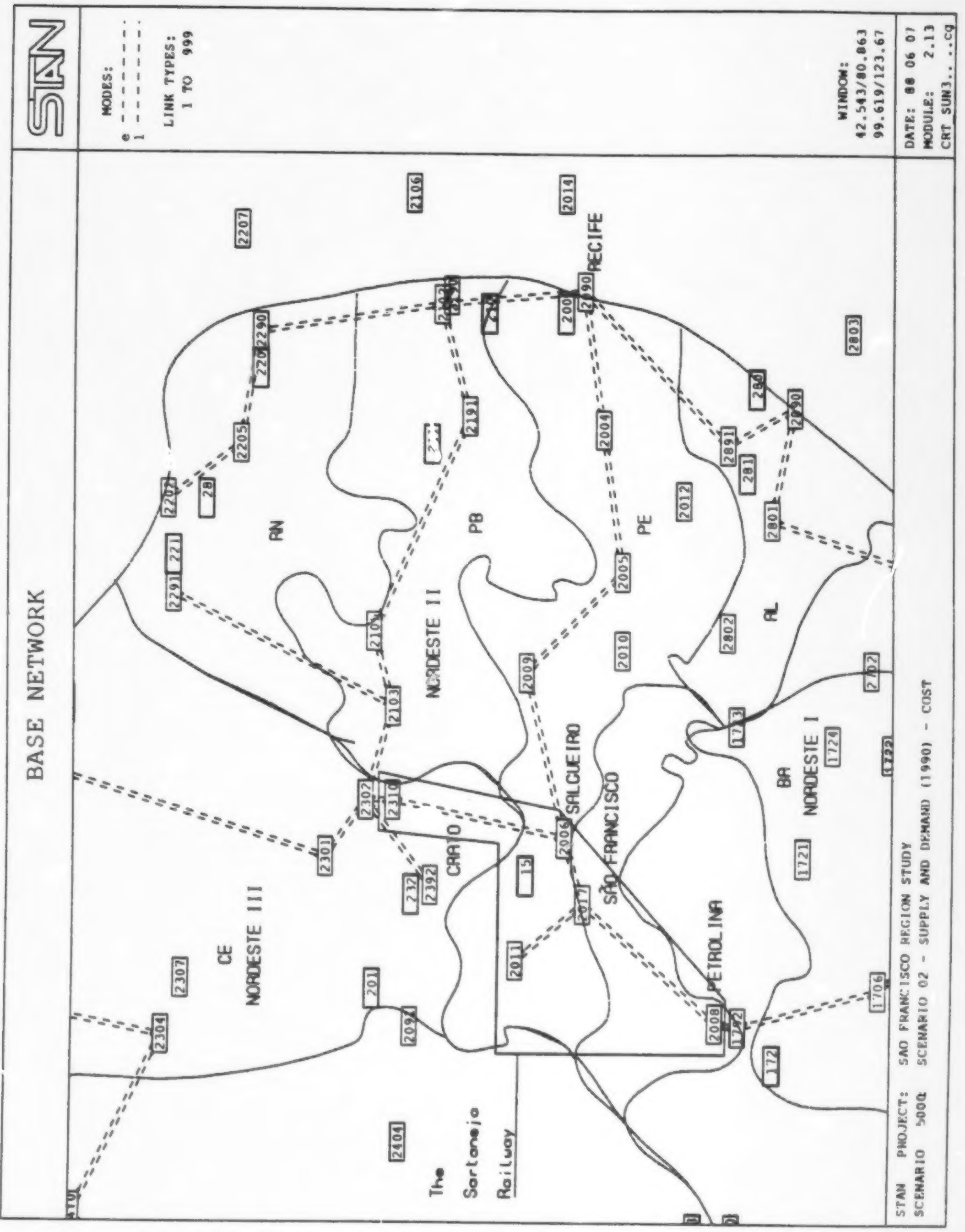

BASE NETWORK
STAN
MODES:
e
l
LINK TYPES:
1 TO 999
WINDOW:
42.543/80.863
99.619/123.67
DATE: 88 06 07
MODULE: 2.13
CRT SUN3.. ..cg
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 500Q SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST
RECIFE
RN
PB
PE
AL
BA
CE
NORDESTE I
NORDESTE II
NORDESTE III
SALGUEIRO
SÃO FRANCISCO
PETROLINA
CRATO
The Sertaneja Railway
2207
2106
2014
2803
2205
2191
2004
2012
2891
2890
2801
2005
2802
2010
2009
2103
2104
2291
2302
2310
2301
2006
2011
2008
1723
1724
1721
1706
1702
2307
2304
201
2094
2404
2392

Figure 7 The "Sertaneja" Railway

Code	Mode	No of Links	Length (km)
p	Paved Road	200	30085
t	Unpaved Road	23	3833
e	Narrow-gauge railway (1.0 m)	84 (89)	13355 (13768)
l	Wide-gauge railway (1.6 m)	12 (12)	1714 (1714)
h	Waterway-inland navigation	8	1683
c	Waterway-coastal navigation	12	4763

Table 1 Link Summary

Intermodal transshipment locations were designated at nodes common to the modal networks considered. In general, the definition of transshipment possibilities at each node was exaustive, that is, all possible mode combinations were permitted, which on the average represents 4 to 6 transshipments per mode. Table 2 shows the summary of transshipments, by mode, for the 144 locations defined for the São Francisco Corridor. Transfers between the centroid mode ("u") and the others are not accounted for in this table. The figures in parentheses have the same meaning as in Table 1. Transshipment between the coastal navigation and the inland transportation modes was permitted at nodes representing maritime ports.

In Figure 3, the solidly filled nodes correspond to transshipment locations, which are defined at more than 70% of the regular nodes defined in the transportation network. In order to illustrate the representation of transshipment possibilities, the Pirapora (1496) and the Petrolina (1972) nodes were selected. Figures 8 and 9 show that at these nodes the paved road (p), waterway (h) and narrow-gauge railway (e) modes meet, in addition to transfers allowed with the centroids having the same name. These locations represent important ports on the São Francisco river which are also integrated with the railway system. The construction of the Transnortheastern

	p	t	e	l	h	c	Total
p	-	43	293 (321)	43	19	24	422 (450)
t	41	-	8 (11)	-	14	-	63 (66)
e	293 (322)	6 (9)	-	15	3	14	331 (363)
l	43	-	15	-	-	3	61
h	19	14	3	-	-	-	46
c	24	-	14	3	-	24	65
Total	420	63 (66)	333 (364)	61	36	65	978 (1041)

Table 2 Transfer Summary

railway introduces additional transshipment possibilities at Juazeiro (2008), Salgueiro (2006) and Ingazeira (2302), principally with the highway mode.

Two scenarios were consequently identified in terms of transportation supply: the current situation and that after the construction of the Transnortheastern railway. The shortening of the travel time by rail resulting from the new connections may benefit, other than the traffic passing through the São Francisco Corridor, the distribution of the production of the gypsum industry, the CODEVASF agricultural projects and the alcohol distilleries.

3.1.3 Transportation Demand

The determination of transportation demand included estimates of origin-destination matrices (O/D desire lines), both current (1987) and for the projection horizon (1990) for the selected products (gypsum, salt, solid agricultural bulk, including rice,

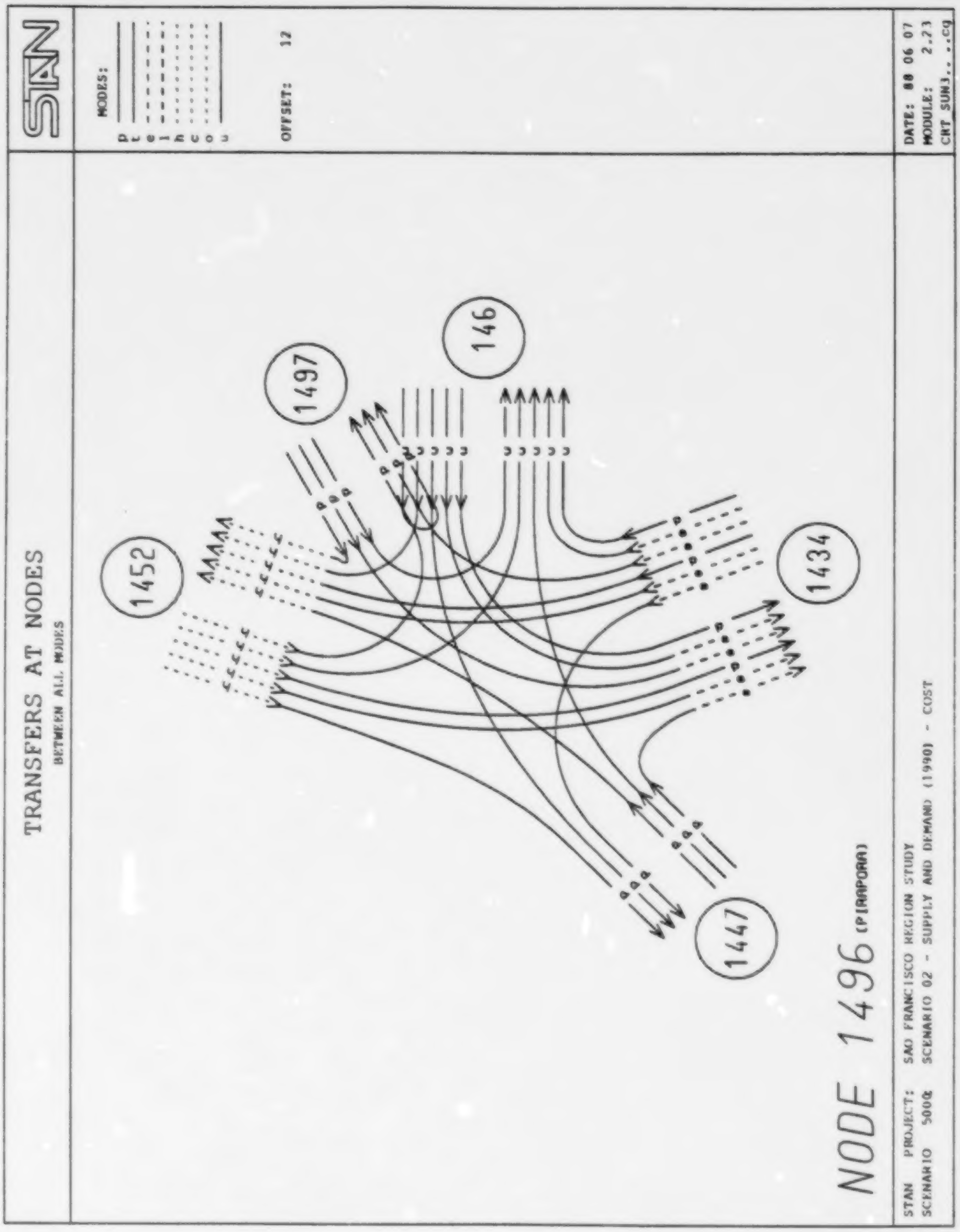

TRANSFERS AT NODES
BETWEEN ALL MODES
STAN
MODES:
p
r
e
l
h
c
o
u
OFFSET: 12
1452
1497
146
1434
1447
NODE 1496 (PIRAPORA)
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 500Q SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST
DATE: 88 06 07
MODULE: 2.23
CRT SUNJ...cg

Figure 8 Transfers at Pirapora

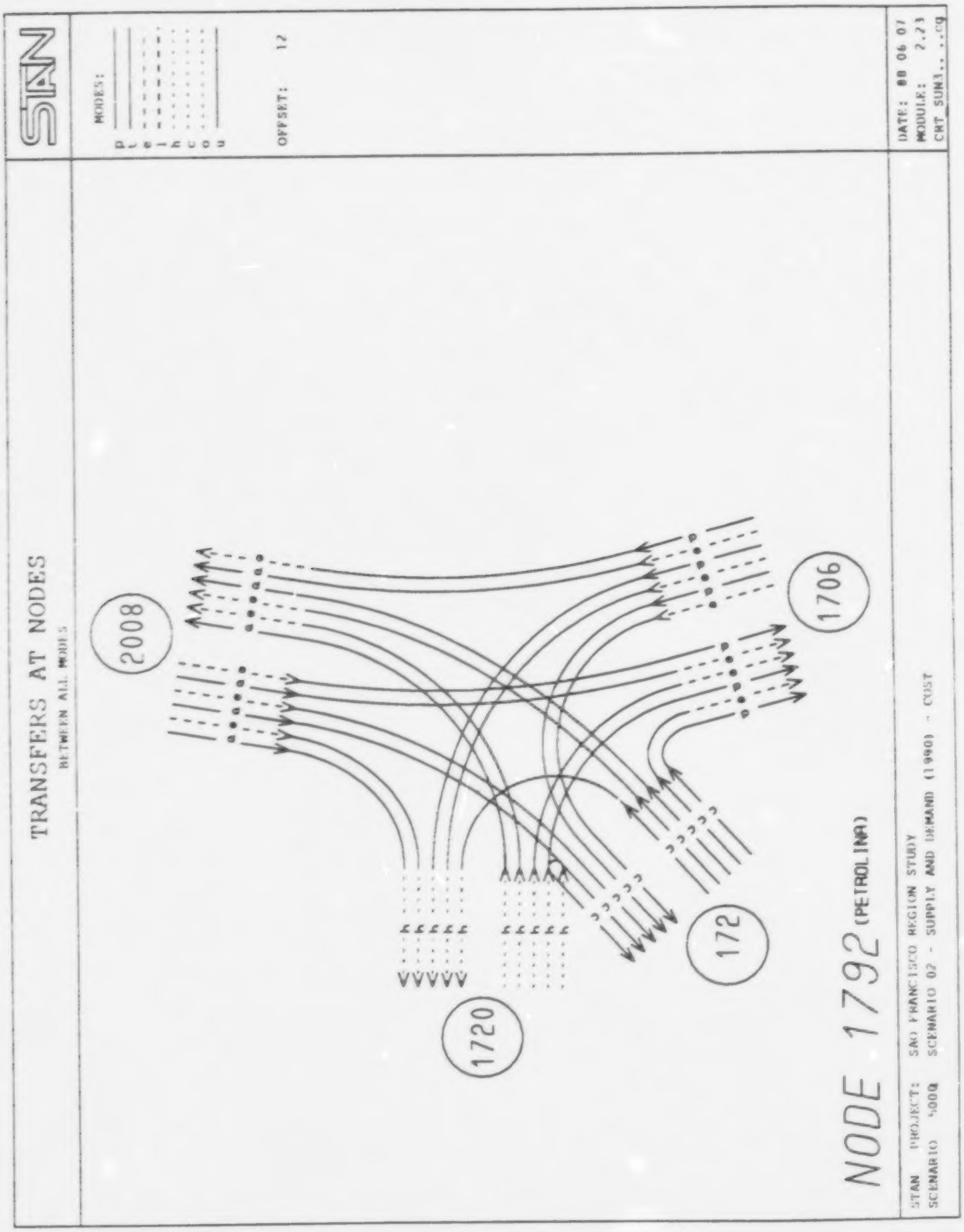

TRANSFERS AT NODES
BETWEEN ALL MODES
MODES:
OFFSET: 12
2008
1706
172
1720
NODE 1792 (PETROLINA)
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 400Q SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST
DATE: 88 06 07
MODULE: 2.23
CRT SUN3.....cg

Figure 9 Transfers at Petrolina

corn, soya bean and bean, cement and petroleum byproducts, including alcohol). These products present important flows that use the transportation system of the São Francisco Corridor, either as transit flows, or as flows originating, or with destination, in its area of direct influence and hence may potentially use the waterway.

The demand estimates were based on secondary information sources, that is, data available from other studies without complementary field surveys. The "Medium São Francisco Navigation Study" (GEIPOT, 1982) and the "Transportation Sector Development Program" (PRODEST, 1987/90), with its scope restricted to the direct and indirect areas of influence of the Corridor, were most important. The O/D matrices in these studies were combined to determine O/D matrices for year 1987. The 1990 demand matrices, on the other hand, were based on total supply and demand estimates for the products, and computed by using matrix balancing procedures, and assuming that current transportation demand structure remains constant.

The superposition of O/D matrices from different studies sought to minimize the effects of the lack of the PRODEST (1987/90) comprehensiveness, since it includes only centers of national relevance, without considering some of the regional flows, principally those of agricultural solid bulk. The hypothesis of a constant demand structure, over the projection horizon, is acceptable for a period of five years, during which only a qualitative evolution of the flows would occur. In both cases, the available information was not validated for the interdependencies of production sectors, since the selected products were not interdependent.

Figures 10 and 11 show the location of the total transportation demand in 1987 in the São Francisco river corridor, in terms of supply (left bar) and demand (right bar) of the centroids considered. The clear predominance of the demand outside its area of direct influence (in a 50:1 proportion), principally along the coast of the Northeast

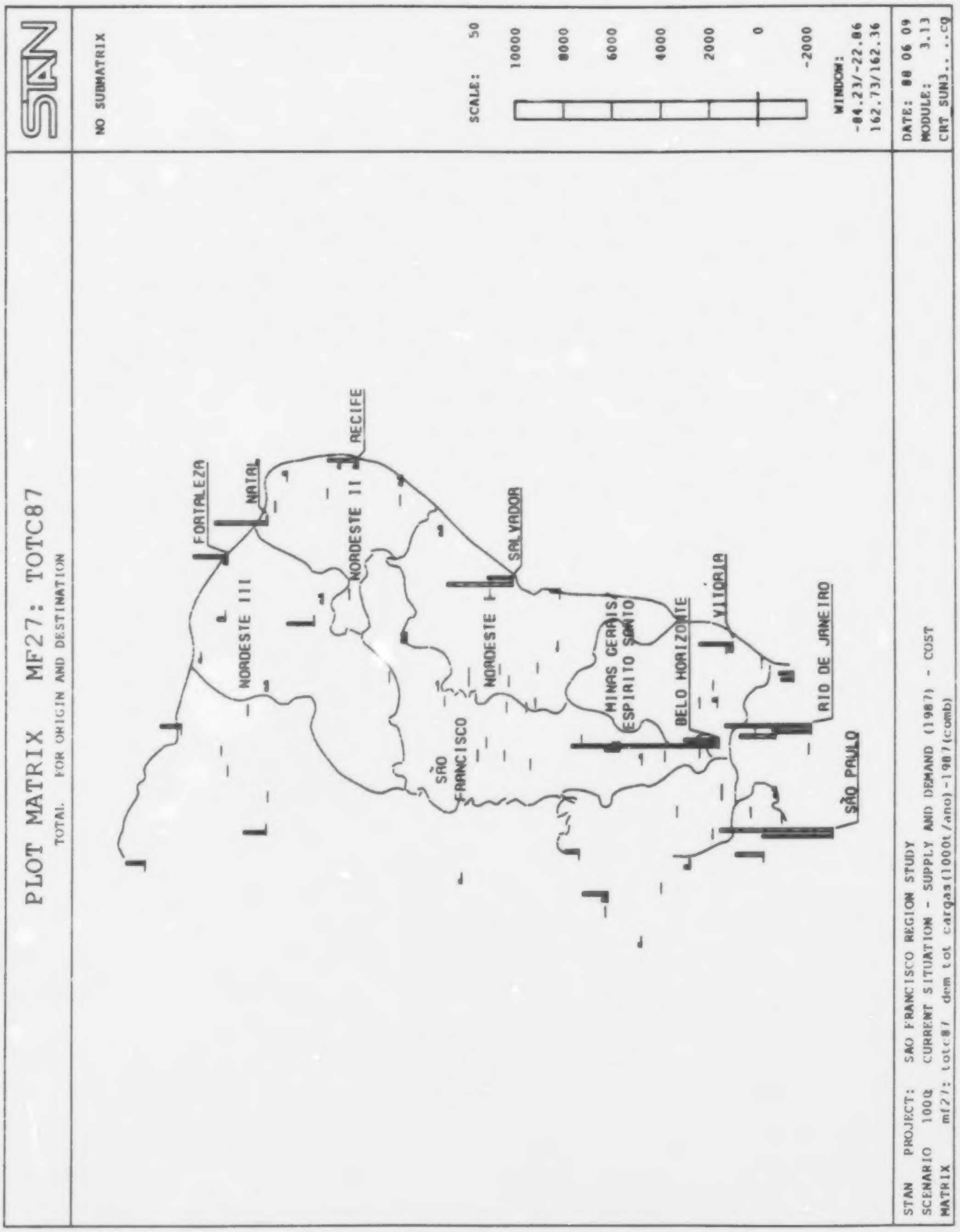

PLOT MATRIX MF27: TOTC87
TOTAL FOR ORIGIN AND DESTINATION
STAN
NO SUBMATRIX
SCALE: 50
10000
8000
6000
4000
2000
0
-2000
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 09
MODULE: 3.13
CRT SUN3...cg
FORTALEZA
NATAL
RECIFE
NORDESTE III
NORDESTE II
SALVADOR
NORDESTE I
SÃO FRANCISCO
MINAS GERAIS ESPIRITO SANTO
BELO HORIZONTE
VITORIA
RIO DE JANEIRO
SÃO PAULO
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100Q CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST
MATRIX mf27: totc87 dem tot cargas(1000t/ano)-1987(comb)

Figure 10 Transportation Demand (1987) - São Francisco River Corridor

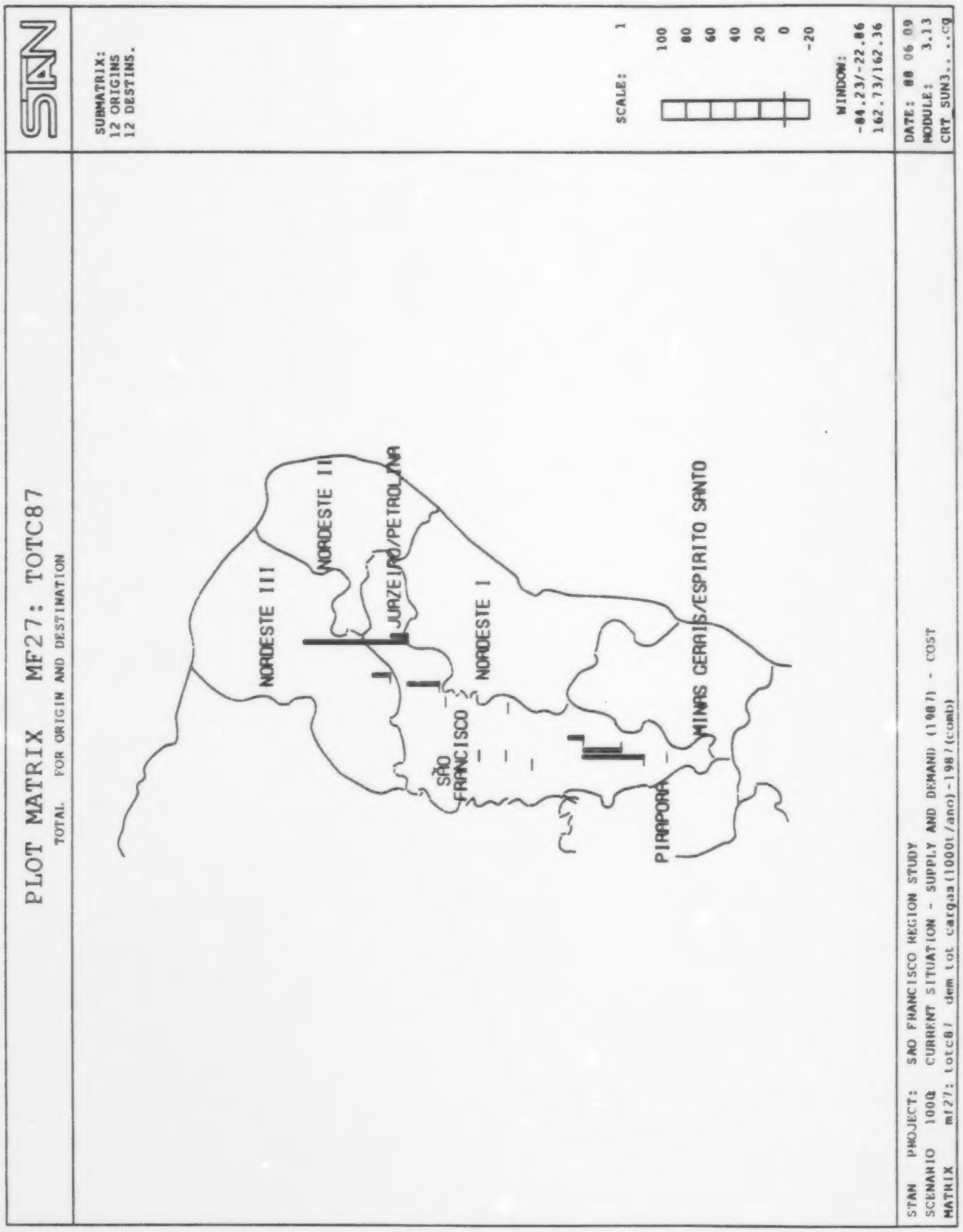
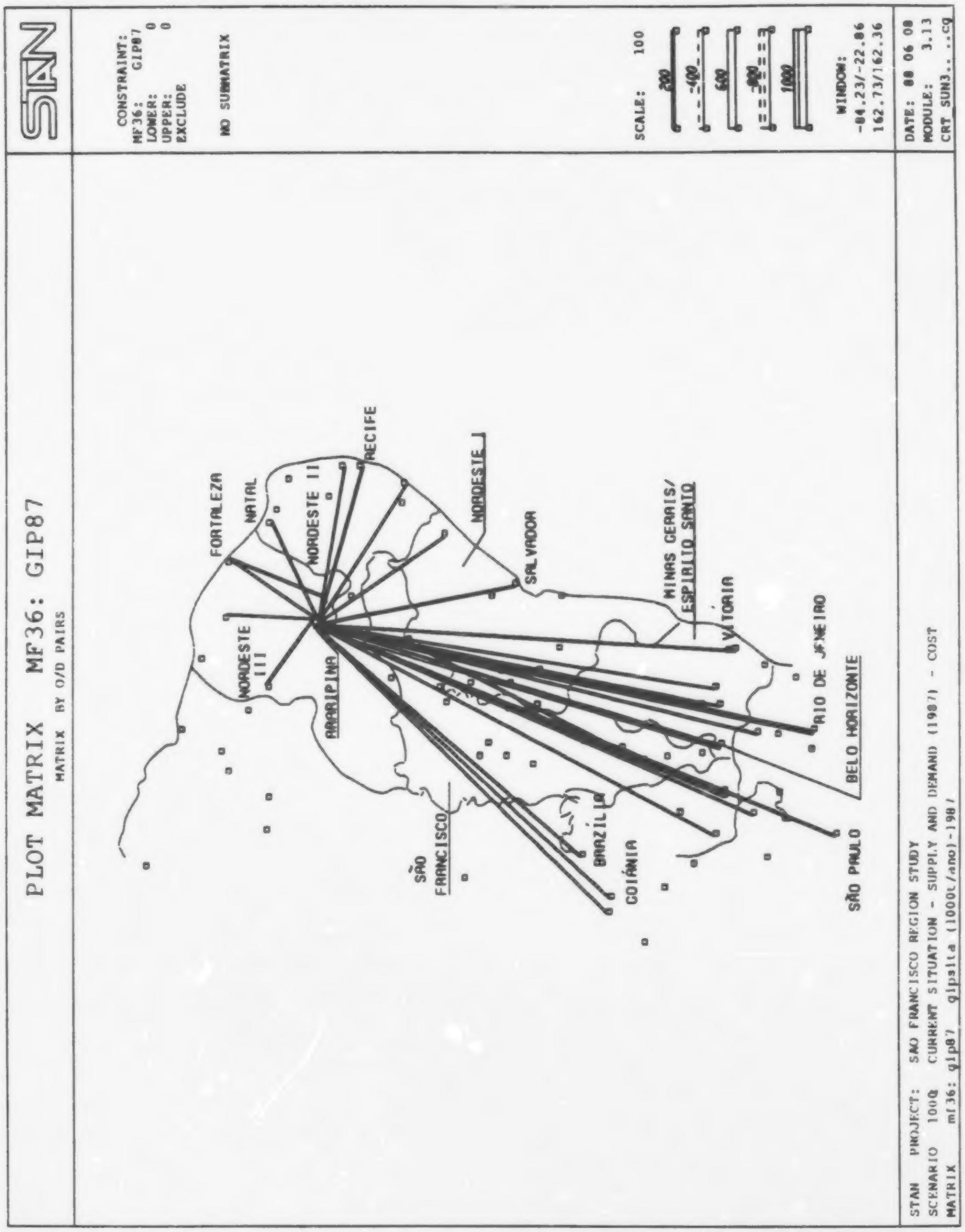

STAN
PLOT MATRIX MF27: TOTC87
TOTAL FOR ORIGIN AND DESTINATION
SUBMATRIX:
12 ORIGINS
12 DESTINS.
SCALE: 1
100
80
60
40
20
0
-20
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 09
MODULE: 3.13
CRT SUN3.. ..c9
NORDESTE III
NORDESTE II
JUAZEIRO/PETROLINA
NORDESTE I
SÃO FRANCISCO
MINAS GERAIS/ESPIRITO SANTO
PIRAPORA
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100Q CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST
MATRIX mf27: totc87 dem tot cargas(1000t/ano)-1987(comb)

Figure 11 Transportation Demand (1987) in the Direct Influence Area

and Center-South regions, may cause a number of distortions in the utilization of the transportation system. On the other hand, it was noted that most coastal centers show a total supply deficit, while Salvador has a demand deficit. The centers within the São Francisco Corridor appear as production centers for the selected products, especially the centers at the extremities of the navigable section of the river. It is important to note the location of several centers in the interior, that have a relative important transportation demand. Particularly, for the selected products, one notes that:

- The region producing gypsum is located at the Chapada de Araripe, in Pernambuco. Gypsum is used by cement industries and civil construction companies, principally in Minas Gerais (see Figure 12);
- The salt flows come from the Rio Grande do Norte saltworks (Mossoró and Macau) and are consumed by the cattle raising exploitations along the area of influence of the corridor and in a number of urban centers in the Southeast (see Figure 13);
- Agricultural solid bulks form the inland flow towards processing industries, e.g. the corn for the Petrolina region and the Maranhão rice to the Center-South region (see Figure 14);
- Cement flows originate in Minas Gerais with destinations within the same Center-South region and in the São Francisco Corridor. A number of industries using cement appear in the Northeast. The forecasted demand for cement in Belém also appears, due to the construction of the Tucuruí dam (see Figure 15);
- The petroleum byproduct flows originate in the major ports, since the location of the refineries that supply the region are in or near ports (for example, in Salvador). It is also noted that the alcohol production is being moved to the west of Bahia (see Figure 16).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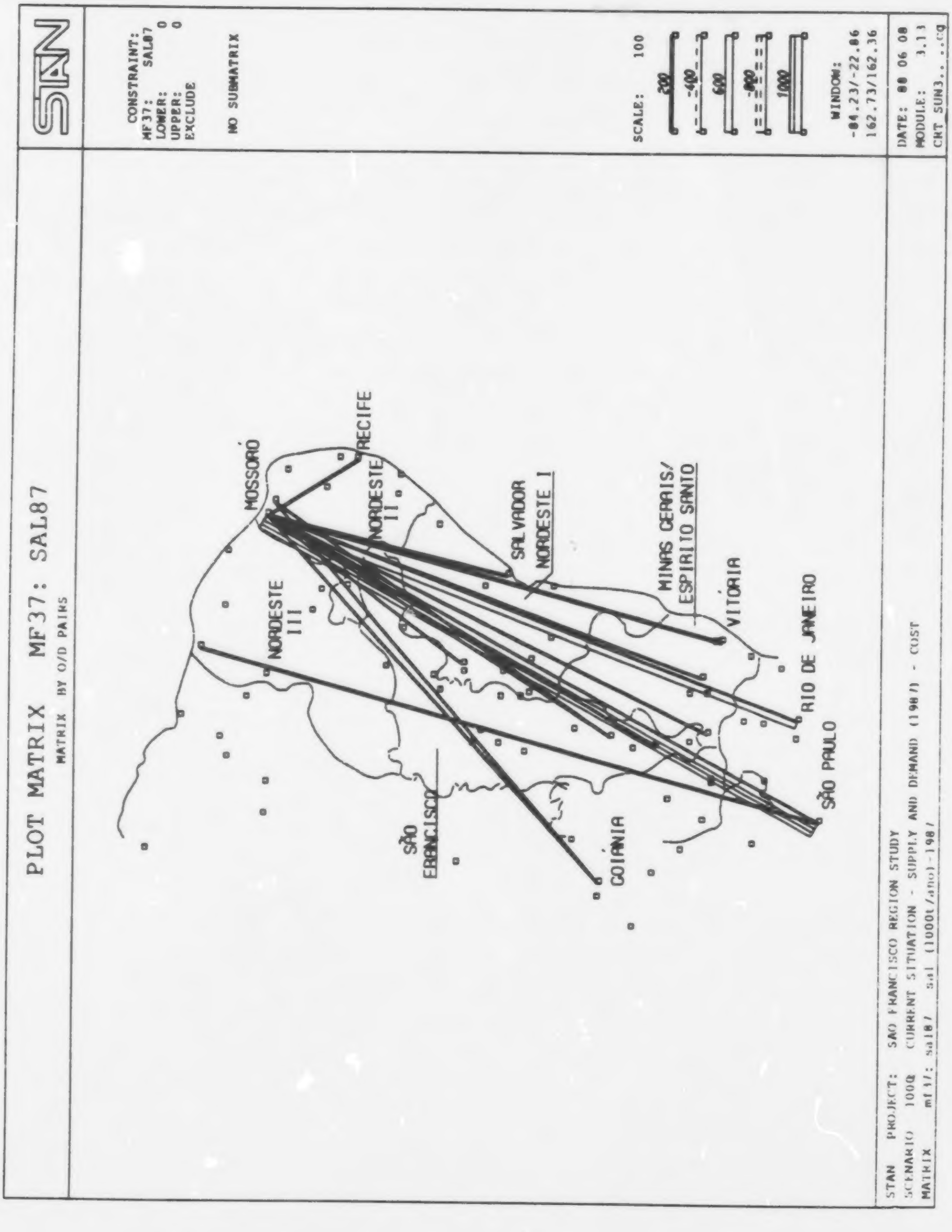
MATRIX BY O/D PAIRS
CONSTRAINT:
MF36: GIP87
LOWER: 0
UPPER: 0
EXCLUDE
NO SUBMATRIX
SCALE: 100
200
400
600
800
1000
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 08
MODULE: 3.13
CRT SUN3... ..cg
FORTALEZA
NATAL
RECIFE
NORDESTE II
NORDESTE I
NORDESTE III
ARARIPINA
SALVADOR
MINAS GERAIS/ ESPIRITO SANTO
VITORIA
RIO DE JANEIRO
BELO HORIZONTE
SÃO PAULO
SÃO FRANCISCO
BRAZÍLIA
GOIÁNIA
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 1000 CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST
MATRIX mf36: gip87 gipsita (1000t/ano)-1987

Figure 12 Gypsum Desire Lines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MATRIX BY O/D PAIRS
STAN
MOSSORÓ
RECIFE
NORDESTE II
SALVADOR
NORDESTE I
MINAS GERAIS/ ESPIRITO SANTO
VITÓRIA
RIO DE JANEIRO
SÃO PAULO
NORDESTE III
SÃO FRANCISCO
GOIÂNIA
SCALE: 100
200
400
600
800
1000

CONSTRAINT:
MF37: SAL87
LOWER: 0
UPPER: 0
EXCLUDE

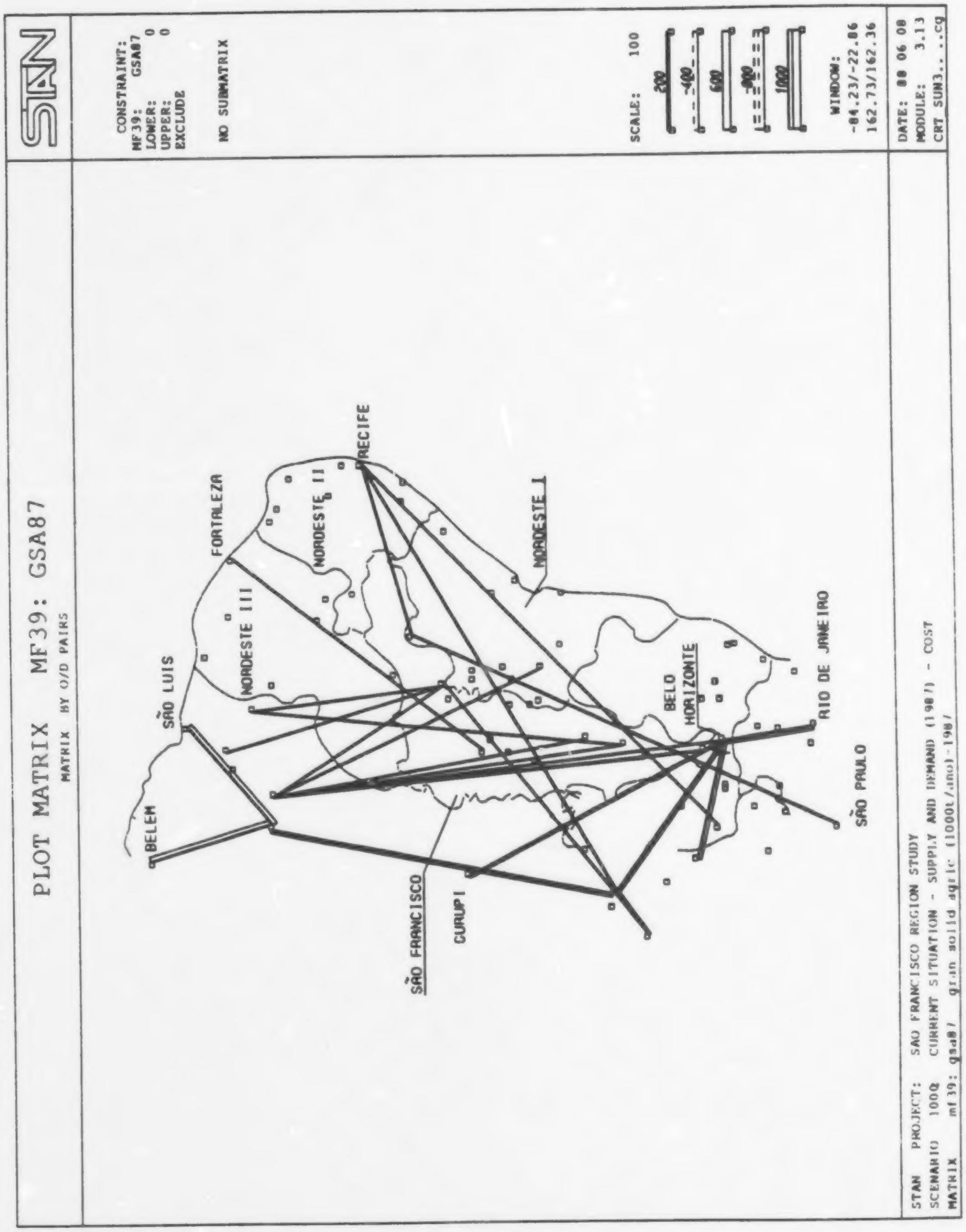
NO SUBMATRIX

WINDOW:
-84.23/-22.86
162.73/162.36

STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100Q CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST
MATRIX mf37: sal87 sal (1000t/ano)-1987

DATE: 88 06 08
MODULE: 3.13
CRT SUN3.....CQ

Figure 13 Salt Desire Lines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MATRIX BY O/D PAIRS
STAN
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UPPER: 0
EXCLUDE
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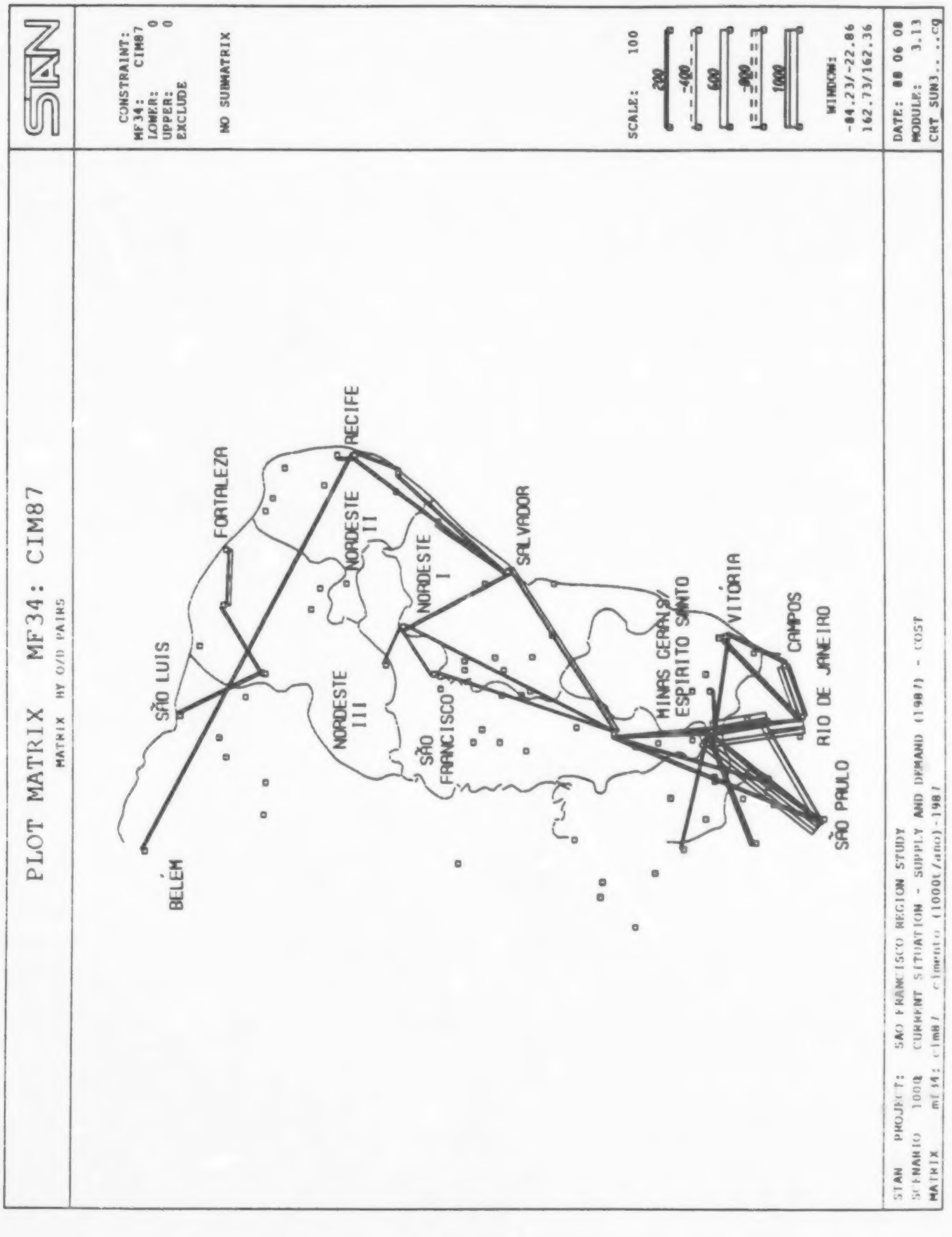
200
400
600
800
1000
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 08
MODULE: 3.13
CRT SUN3....cg
BELEM
SÃO LUIS
FORTALEZA
NORDESTE III
NORDESTE II
RECIFE
NORDESTE I
BELO HORIZONTE
RIO DE JANEIRO
SÃO PAULO
SÃO FRANCISCO
GURUPI
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100Q CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST
MATRIX mf39: gsa87 gran solid agric (1000t/ano)-1987

Figure 14 Desire Lines for Agricultural Solid Bulks



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MATRIX BY O/D PAIRS
STAN
CONSTRAINT:
MF34: CIM87
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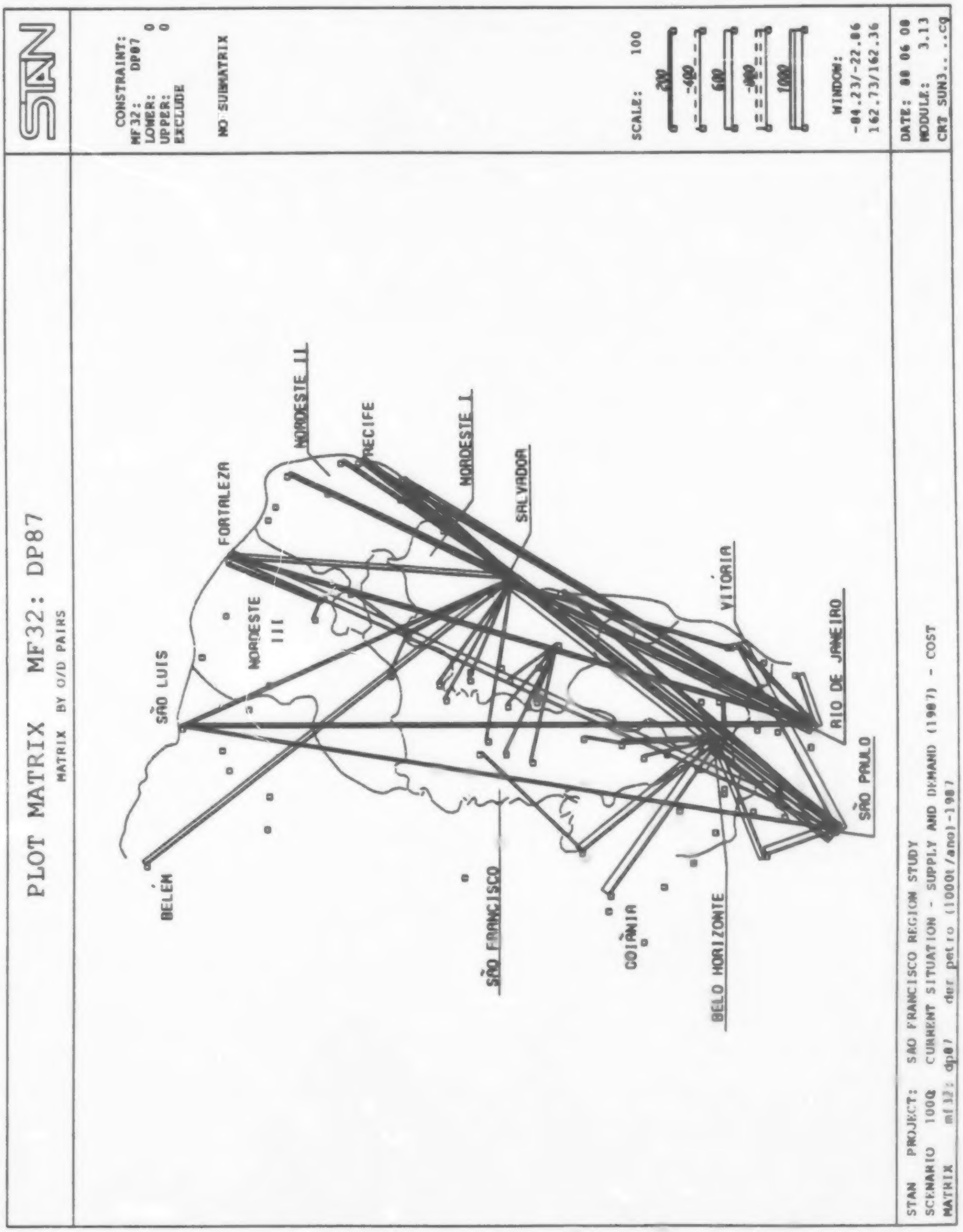
UPPER: 0
EXCLUDE
NO SUBMATRIX
SCALE: 100
200
400
600
800
1000
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 08
MODULE: 3.13
CRT SUN3.. ..C9
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 1000 CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST
MATRIX mf34: cim87 cimento (1000t/ano)-1987
BELÉM
SÃO LUIS
FORTALEZA
RECIFE
NORDESTE II
NORDESTE I
NORDESTE III
SALVADOR
SÃO FRANCISCO
MINAS GERAIS/ESPIRITO SANTO
VITÓRIA
CAMPOS
RIO DE JANEIRO
SÃO PAULO

Figure 15 Cement Desire Lines


PLOT MATRIX MF32: DP87
MATRIX BY O/D PAIRS
STAN
CONSTRAINT:
MF32: DP87
LOWER: 0
UPPER: 0
EXCLUDE
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SCALE: 100
200
400
600
800
1000
WINDOW:
-04.23/-22.86
162.73/162.36
DATE: 88 06 08
MODULE: 3.13
CRT SUN3... .cg
BELEM
SÃO LUIS
FORTALEZA
NORDESTE III
NORDESTE II
RECIFE
NORDESTE I
SALVADOR
SÃO FRANCISCO
GOIÂNIA
BELO HORIZONTE
VITÓRIA
RIO DE JANEIRO
SÃO PAULO
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100Q CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST
MATRIX mf32: dp87 der petro (1000t/ano)-1987

Figure 16 Desire Lines for Petroleum Byproducts

Table 3 quantifies the 1987 and 1990 transportation demand for the selected products, according to four types of desire lines: within the São Francisco Corridor, from inside the corridor toward the outside (export), from the outside toward the corridor (import) and the transit traffic. These last values also include flows within the corridor which were accounted for in the area of indirect influence of the São Francisco river. One notes the predominance of the latter, with more than 90% of the total demand, a trend confirmed for all the products and years considered. Alcohol is significant for the export flows of the corridor (it is included as a petroleum byproduct), whereas for import flows, cement is a significant product. The flows within the corridor are relatively small and do not represent any demand increase during the 1987-1990 period. It is worth stressing that the total demand identifies two major groups of products: petroleum byproducts and cement, with flows in excess of 7 million tons/year and gypsum, salt and agricultural solid bulks with flows below 3 million tons/year.

No additional considerations are needed when considering the projection of transportation demand for 1990, since it was assumed that its current structure will be maintained. There was an average increase of 16% of total demand, with cement and petroleum byproducts occupying the pre-eminent position. Figure 17 shows a comparative histogram for the total demand matrices for 1987 and 1990, for flows over 100 000 tons/year. It is noteworthy, however, that the average of the flows is around 50 000 tons/year, with small variations between the considered years. Desire lines over 250 000 tons/year appear only for frequencies under 10 origin/destination pairs. In these cases, the demand increases by invervals of 200 000 tons/year.

In terms of the definition of scenarios resulting from the demand analysis, the years 1987 and 1990 were differentiated. A scenario that includes the Transnortheastern railway was considered only for 1990. A priori analyses were not performed concerning the modal split of the flows for the selected products, since the location of the demand determines the modes that will be used.

Product	In-Corridor		Export		Import		Transit	
	1987	1990	1987	1990	1987	1990	1987	1990
Gypsum	50.0	(60.0)	-	(-)	95.0	(105.0)	1090.5	(1221.5)
Salt	-	(-)	-	(-)	6.5	(6.5)	2274.1	(2563.6)
Agricultural Solid Bulks (rice, corn, soya bean and bean)	-	(-)	40.0	(39.1)	33.1	(33.1)	1910.3	(2040.8)
Cement	51.0	(51.8)	637.0	(802.8)	-	(-)	6318.0	(7424.2)
Petroleum Byproducts	15.6	(15.6)	13.6	(13.6)	421.2	(474.4)	9450.3	(11196.3)
TOTAL	116.6	(126.6)	690.6	(855.8)	558.8	(619.0)	21056.7	(24446.5)

Note: The values in parentheses are demand projections for year 1990.

Table 3 Transportation Demand (in 1000 t/year)

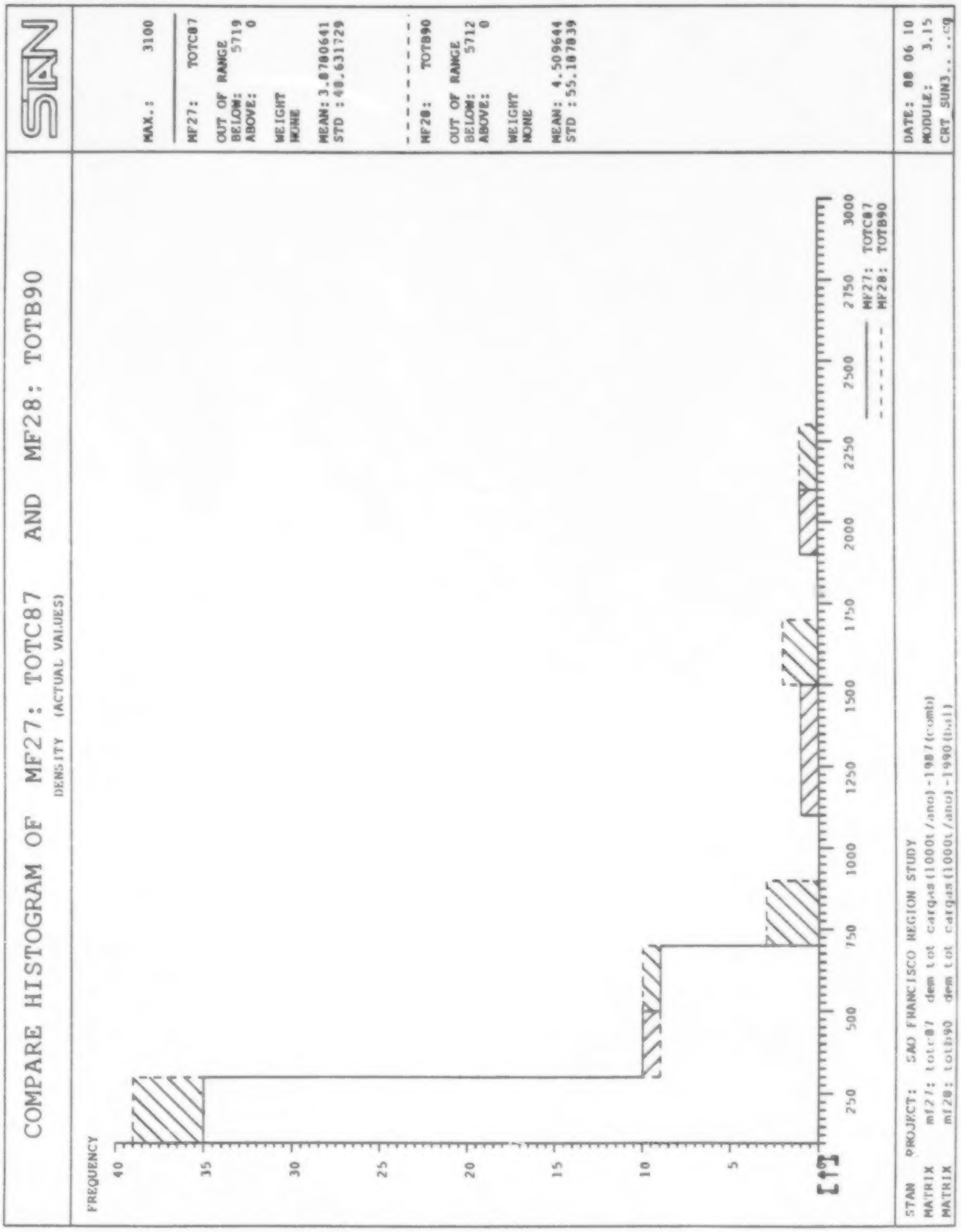


Figure 17 1987/1990 Total Demand Comparison

3.1.4 Unit Costs and Functions

Two cost criteria were used to assign freight on the network of the São Francisco Corridor: operating cost and time delay. Considering the different calculation bases, monetary and hourly, these criteria were used separately in the evaluation of the generalized cost for the different scenarios. Thus, the operating cost items measured on an hourly basis (e.g. vehicle depreciation and driver wages) were converted to a distance basis, as a function of travel speed on the links of the transportation network.

To determine unit (operating and time) costs, it was necessary to characterize the typical vehicle for each product in each mode, both in terms of capacity and gross weight. The identification of the typical vehicles was performed by using the approach and the fleet utilization coefficients already defined in Chapter 3, Part IV. In addition to the evaluation of unit costs and times, the definition of typical vehicles permitted an estimation of the fleet required to meet the transportation demand for the products, without consideretion of the empty backhaul.

Three vehicle classes were identified for the highway mode: light trucks, middle-size trucks, and heavy trucks. The fleet utilization coefficients were determined for the various products (agricultural and mineral solid bulk, liquid bulk and general cargo) by taking as reference a product for which reliable information was available. The cathegorization of the selected products took into consideration the most common packaging type for their transportation within the area of influence of the São Francisco Corridor. Likewise, six ship classes were identified for coastal navigation (in terms of gross weight). The fleet utilization coefficients for the same freight types were computed by considering the average utilization rate (%) of the ship capacity and the stowage factor (t/m^3) by product. For the railway and inland navigation modes, the observed average capacity of the vehicles transporting each product in the corridor and typical convoy were adopted. For the rail, the convoys, or trains, are determined according to the number of locomotives used in product compositions and the traction factors of these locomotives in each section. For the waterway, a typical convoy made up of six flats was considered.

The chosen functions, in monetary and time terms and according to the typical vehicles, are shown in Tables 4 to 12 (see Chapter 3, Part IV, for details on how these figures may be obtained). The functions are linear with distance, and hence have a constant marginal cost. Only in the case of railway travel time, a volume/delay function (defined as an approximation of Peterson's formula, see Chapters 4 and 7, Part II) was adopted, which translates congestion on single rail lines into a function of the number of trains and the capacity of the section (see Figure 18). It is worth noting that the general Price Index (Cr$87/Cr$80 = 0.53349 for road and rail and Cr$87/Cr$81 = 0.27574 for navigation - Conjuntura Econômica, 1987) were used to update the monetary values available in the information sources.

To define unit costs on transfers, a distinction was made between land to land and land to water transshipments. The classification of the products according to their modal vocation, storage and packaging type, was also taken into account since these are factors capable of influencing their handling. While for maritime ports there was a substantial variation between groups of products, for the river ports this variation was not significant, allowing average values to be adopted for the latter. On the other hand, calculation of unit impedances (costs and delays) did not consider distance, but only the freight volume moved. In order to restrict the utilization of inland and coastal navigation, values for transshipment capacity in ports were estimated. Tables 13 to 15 present the information required for the specification of impedance functions at transshipment locations. As vehicles do not have to be defined on transfers, the movement unit is thus the ton of freight.

Cargo Type / Vehicle	Solid Bulk			Liquid Bulk	General Cargo
	Agricultural		Mineral		
	Grain	Meal			
Fleet Utilization (%)					
Light truck	1.3	5.6	3.5	-	-
Middle truck	14.4	29.7	26.8	47.5	27.7
Heavy truck	84.3	64.7	69.7	52.5	56.0
Typical Vehicle					
Capacity (t)	22.9	20.5	19.6	19.0	17.5
Gross Weight (t)	36.7	32.6	32.8	30.9	29.6
Products	Rice, Corn, Soya bean and castorbean	Soya meal	Gypsum	Petroleum Byproducts	Cement,Salt, and Sugar
Reference (Product Considered)	Soya bean	Soya meal	Mineral coal	Soya oil, with no participation of light trucks	Cement sacks

Table 4 Road Typical Vehicles

Vehicle	Road Profile	Paved			Unpaved			⟵ Pavement
		Good	Fair	Poor	Good	Fair	Poor	⟵ Maintenance State
Light Truck	Level	5.69	6.31	7.13	7.22	8.37	13.30	
	Undulated	5.76	6.39	7.25	7.34	8.56	14.14	
	Mountainous	5.78	6.43	7.30	7.40	8.65	14.57	
Middle Truck	Level	9.40	10.39	11.70	11.70	13.09	16.31	
	Undulated	9.60	10.61	11.98	12.45	13.43	16.86	
	Mountainous	9.94	11.01	12.91	13.09	14.00	17.75	
Heavy Truck	Level	16.92	17.97	19.38	19.38	20.32	22.30	
	Undulated	17.15	18.23	19.53	19.68	20.68	22.75	
	Mountainous	19.27	20.38	21.86	21.86	22.91	25.14	

Note: The influence of horizontal geometry was not considered.

Table 5a Road Operating Costs

Cost Function	$=(COP_l * \%Light+COP_m * \%Middle+COP_p * \%Heavy)/CAP*EXT$ Where COP_i = operating cost for light (l), middle (m) and heavy truck (p) % = utilization of light (l), middle (m) and heavy (p) truck fleet CAP = capacity of typical truck EXT = length of road section

Table 5b Road Operating Cost Function
Table 5 Road Operating Cost Characteristics

Vehicle	Road Profile	Paved			Unpaved			← Pavement
		Good	Fair	Poor	Good	Fair	Poor	← Maintenance State
Light Truck	Level	65.6	63.1	58.4	55.4	50.3	39.8	
	Undulated	63.6	61.3	56.8	54.0	49.0	39.9	
	Mountainous	61.2	58.9	56.8	52.2	47.6	38.1	
Middle Truck	Level	62.7	61.3	56.1	52.3	47.0	36.7	
	Undulated	54.7	55.9	51.6	48.6	44.0	34.9	
	Mountainous	54.6	51.6	48.1	45.5	41.5	33.6	
Heavy Truck	Level	66.7	62.0	51.9	43.2	38.6	29.2	
	Undulated	58.5	54.8	47.0	40.2	36.3	28.2	
	Mountainous	53.7	50.5	43.7	38.1	34.7	27.4	

Note: The influence of horizontal geometry was not considered.

Table 6a Speed of Road Vehicles

Time Function	$= (1/VEL_L * \%Light + 1/VEL_M * \%Middle + 1/VEL_P * \%Heavy)*EXT$ Where VEL_i = speed of light (L), middle (M) and heavy (P) truck % = utilization of light (L), middle (M) and heavy (P) truck fleet CAP = capacity of typical truck EXT = length of road section

Table 6b Road Delay Function

Table 6 Road Delay Characteristics

Vehicle Product	Typical Wagon		No. of Locomotives by Train
	Capacity (t)	Gross Weight (t)	
Rice	30	40	1
Corn and soya bean	40	55	1
Gypsum	40	50	2
Petroleum byproducts	30	46	3
Cement	40	55	1
Salt and sugar	40	55	1

Table 7 Characteristics of Railway Vehicles by Product

Region	Item			
	Gross ton-km	Trains-km	Locomotives-km	Wagons-km
Sp 1.1 (Fortaleza)	0.02768	4.64554	10.84368	0.39760
Sp 1.2 (Recife)	0.04320	11.20169	18.54627	1.91142
Sr 7	0.02765	4.89374	20.52866	1.58149
S.-E. Metric.Gauge	0.05655	21.16890	23.01850	1.42000
S.-E. Wide Gauge	0.04486	24.54590	52.62030	1.11230
Fepasa	0.04286	17.41310	17.35440	2.25310

Table 8 Operating Costs For Railway Vehicles

Cost Function = LENGTH * ((1 + TARE/CAP) * (Ton-km + (Trains-km/(ALFA * BETA)) + (Locos-km/BETA) + (1/CAP) * Wagons * KM)

Time Function = (LENGTH/SPEED) * (1+(A * TRAIN)+B * (TRAIN/CAP)^6

Where

Ton-km, Trains-km,
Locos-km and
Wagons-km = Unit cost

TARE, CAP = Weight and capacity of typical wagon

ALFA = No. of locomotives by train

BETA = Traction capacity of standard locomotive. The typical locomotive for the study area is the GE-U10B, whose traction capacity, 250t<BETA<1517, was determined as a function of railway sections

LENGTH = Length of railway section

SPEED = Train speed as a function of railway sections characteristics

TRAIN = No. of trains on railway sections $\left(\frac{\text{Cargo Volume (t)}}{\text{ALFA}\cdot\text{BETA}}\right)$

EXT,CAP = Length and capacity (trains/day) of railway sections

A,B = Coefficients determined through regression analysis of empirical data (A=1.1/CAP and B=4.144).

Table 9 Rail Cost and Delay Functions

Link	Cost
Pirapora-Juazeiro-Pirapora	0.267
Pirapora-Bom Jesus da Lapa-Pirapora	0.623
Pirapora-Januária-Pirapora	0.520
Barreiras-Pirapora-Barreiras	0.472

Capacities
of the
Vehicle (Flats): solid bulk and general cargo = 330 t
liquid bulk and general cargo = 360 t
empty weight = 100 t

Convoys: 6-Flat (2+2+2) and one propeller
Cost Funcion = Cunit * LENGTH
Time Funcion = 1/SPEED * LENGTH
Where Cunit = unit operating cost
(adopted Cz$ 267/t.km)
SPEED = convoy speed
LENGTH = length of waterway section

Note: With the construction of the Transnortheastern Railway the following improvements were admitted for the water mode:

- unit operating cost = Cz$ 153/t.km
- convoy speed - 15 kmh (Pirapora-Petrolina) and 10 kmh (Petrolina/Pirapora)

Table 10 River Navigation Characteristics

Cargo Type		Solid Bulk			Liquid Bulk	General Cargo
		Agricultural		Mineral		
Vehicle		Grain	Meal			
Fleet Utilization (%)						
Cargo Ships	3675	-	30.1 (50.5)	-	-	-
	5200	20.0 (28.0)	29.5 (49.5)	-	50.0 (61.6)	-
	6723	-	-	-	31.2 (38.4)	27.1 (45.6)
	7200	31.5 (44.0)	-	-	-	-
	7400	-	-	-	-	-
Bulk Ships	15000	20.0 (28.0)	-	74.5 (100.0)	-	-
Typical Vehicle						
Capacity (t)		7814.0	4223.0	14050.0	5284.0	6553.0
Capacity Utilization(%)		63.2	66.0	26.3(1)	64.6	46.7
Gross Weight		8824.0	4429.0	15000.0	5785.0	7091.0
Stowage Factor (t/m^3)		0.75	0.77	0.91	0.83	1.43 (cement) and 1.0 (salt,sugar)
Products		rice, corn, soya bean and castorbean	soya meal	gypsum	petroleum byproducts	cement, salt, and sugar
Reference (Products Considered)		soya bean	soya meal	mineral coal	soya oil (liquid bulk)	cement (sacks)

Note: (1) Small sample.

The values in parentheses represent corrected percent values for the sizes of typical ships (DWT).

Table 11 Characteristics of Coastal Navigation Ships

Ship Size		Speed (Knots)	Operating Cost
Cargo Ships	3673	10.0	0.08502
	5200	11.5	0.06688
	6723	14.0	0.07224
	7200	11.2	0.06143
	7400	12.0	0.08838
Bulk Ships	15000	14.5	0.05798

Cost Function = Cunit * LENGTH/FEST
Time Function = 1/SPEED * LENGTH

Where: Cunit = Unit operating cost ($/t-km)
LENGTH = Length of waterway section
FEST = Product stowage factor
SPEED = Speed of typical ship (knots)

Table 12 Coastal Navigaion Unit Costs and Functions

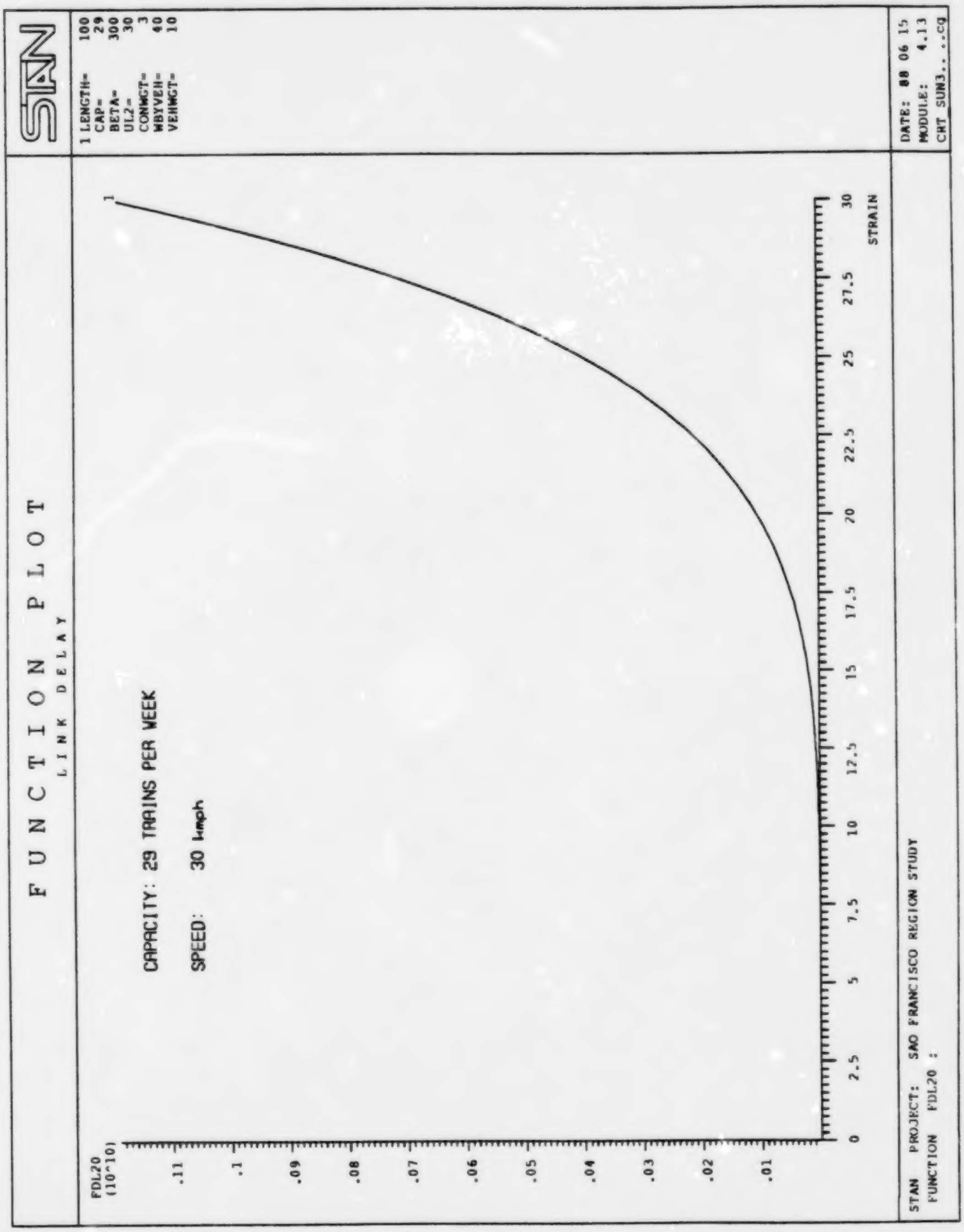


Figure 18 Rail Volume/Delay Function

Cargo Type Ports	General Cargo		Solid Bulk		Liquid Bulk	
	Capacity (t)	Productivity (t/h)	Capacity (t)	Productivity (t/h)	Capacity (t)	Productivity (t/h)
Maritime Ports						
Natal, Maceió, Aracaju	1,000,000	20.0	-	-	-	-
São Luís, Fortaleza, Cabedelo, Vitória	2,000,000	19.2	2,000,000	47.3	-	-
Belém	2,000,000	19.8	-	-	1,000,000	248.7
Recife, Salvador, Rio de Janeiro, Santos	5,000,000	30.6	9,000,000	58.0	15,000,000	141.8
River Ports						
Barra, Xique-Xique, Bom Jesus da Lapa, Januária	100,000	11.0	-	-	-	-
Juazeiro/Petrolina, Ibotirama	200,000	34.4	300,000	15.2	-	-
Barreiras	10,000(1)	3.0(1)	-	-	400,000	28.8
Arapora	700,000	144.6	400,000	55.1	600,000	105.8
Products						

Note: (1) The quantity handled is not significant.

Table 13 Port Characteristics

Group	Description	Products
1	Railway vocation, open air storage	Gypsum
2	Highway vocation, general freight, open air storage or covered warehouses or special storage	Sugar and castorbean
3	Modal competition vocation, solid bulk, open air storage or covered warehouses or siloes	Sugar, salt, soyabean, cement and corn
4	Modal competition vocation, liquid bulk, tank storage	Petroleum byproducts
5	Modal competition vocation, general freight, open air storage or covered warehouses	Rice

Table 14 Product Classification

Transshipment	Product Groups				
	1	2	3	4	5
Land-Water					
Maritime Port	22.01	252.60	89.60	19.62	192.61
River Port	-	-	82.72	-	-
Land-Land	54.06	54.06	125.02	5.52	52.01

COST FUNCTION = CUNIT
TIME FUNCTION = (1/PROD)*(VOL.LE.CAP)+(1/PROD+2*(VOL-CAP))*
(VOL.GT.CAP)

Where CUNIT = Unit operating cost ($/t)
PROD = Transshipment operation productivity (t/h)
CAP = Transshipment capacity (t)
VOL = Cargo volume handled (t)

Table 15 Transfer Unit Costs and Functions

Functions on transfers are also linear, except for delay functions that reflect the capacity of river and maritime ports. Both the unit costs and the productivity rates reflect average values in transshipment operations without identifying the equipment used. The cost information was also updated according to the General Price Index in Brazil (Cr$87/Cr$77=2.206, Conjunctura Econômica, 1987). Figure 19 displays some examples of function plots that show the capacity effect. It is important to note that these functions were determined for groups of transshipment locations classified according to their capacity and productivity, with one function for the land to land case and four for the case of transfers at river and maritime ports.

In order to compare the impedances for each mode, Figures 20 to 29 show plots of time and cost link functions for each product. The hypotheses considered for function evaluations correspond to the average characteristics of links for paved and unpaved road sections (regular maintenance state and undulated vertical geometry) and those of railway sections in the Production Superintendency of Fortaleza (30 km/h speed, 29 trains/week capacity, number of trains assigned to the section representing 5% of the capacity and locomotive traction of 300, 650 and 1517 tons). In general, the relative position of the curves, from larger to smaller impedance, was the following:

- for operating cost

unpaved road	paved road	inland navig.	coastal navig and rail (300t)	rail (650 t)	rail (1517t)

- for time

inland navig. (Petrolina-Pirapora)	coastal navig.	rail.	inland navig. (Pirapora-Petrolina)	unpaved road	paved road

These relations are not indicative of the routes used for freight, since the differences in route length, railway congestion and port capacity play an important role, especially when the time criterion is considered. The possibilities of modal integration were not reflected in these graphs either, nor were the transshipment impedances.

For the scenarios considering the Transnortheastern railway, the characteristics adopted for the new railway were the same as those of the other lines in the same jurisdiction (Production Superintendency of Fortaleza - SP1.1), but improvements in the São Francisco waterway were included, according to information obtained from other studies. No investments were projected for the highway system, neither in terms of new construction, pavement upgrade, or maintenance.

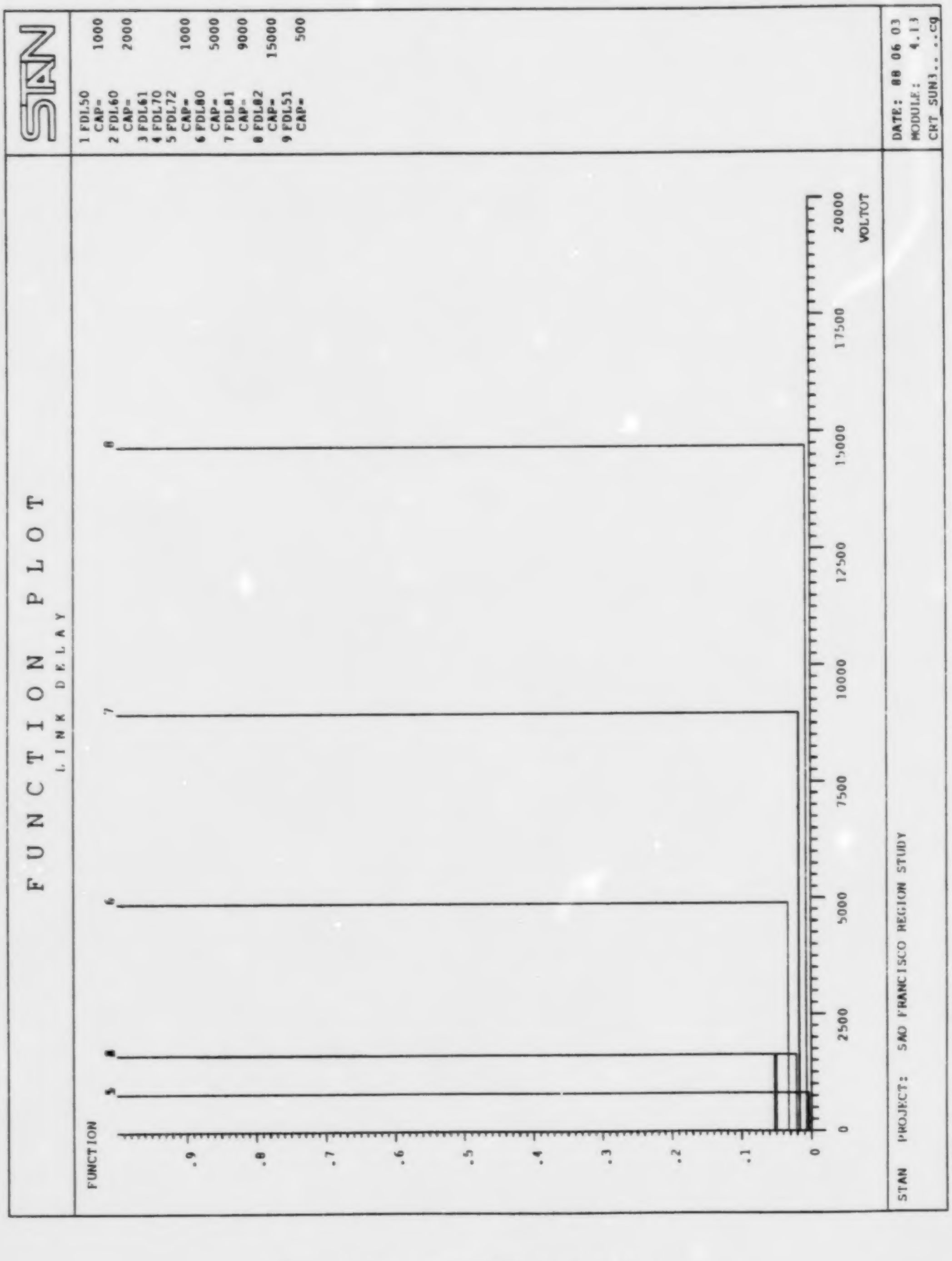


Figure 19 Port Delay Functions

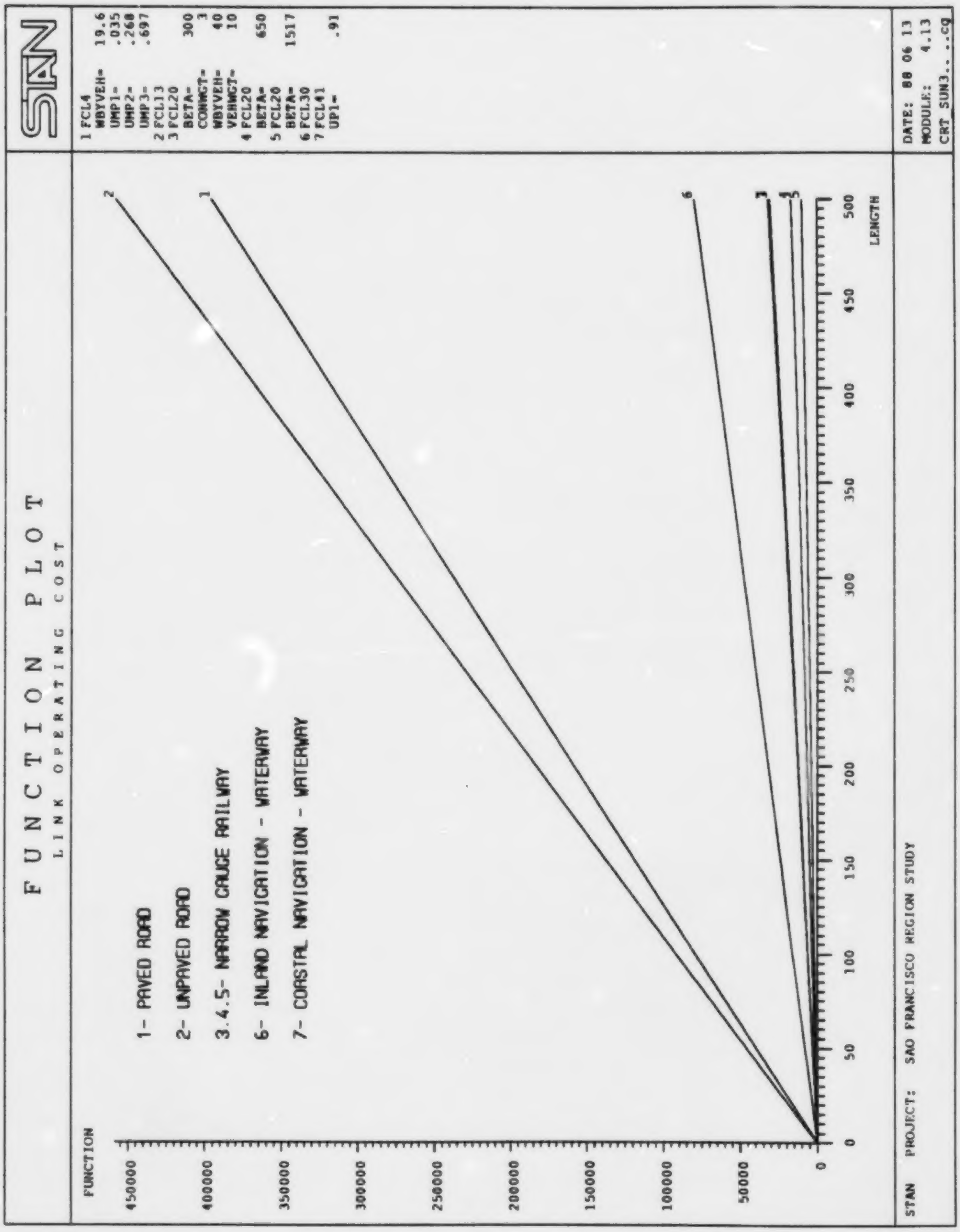


Figure 20 Gypsum Link Cost Functions

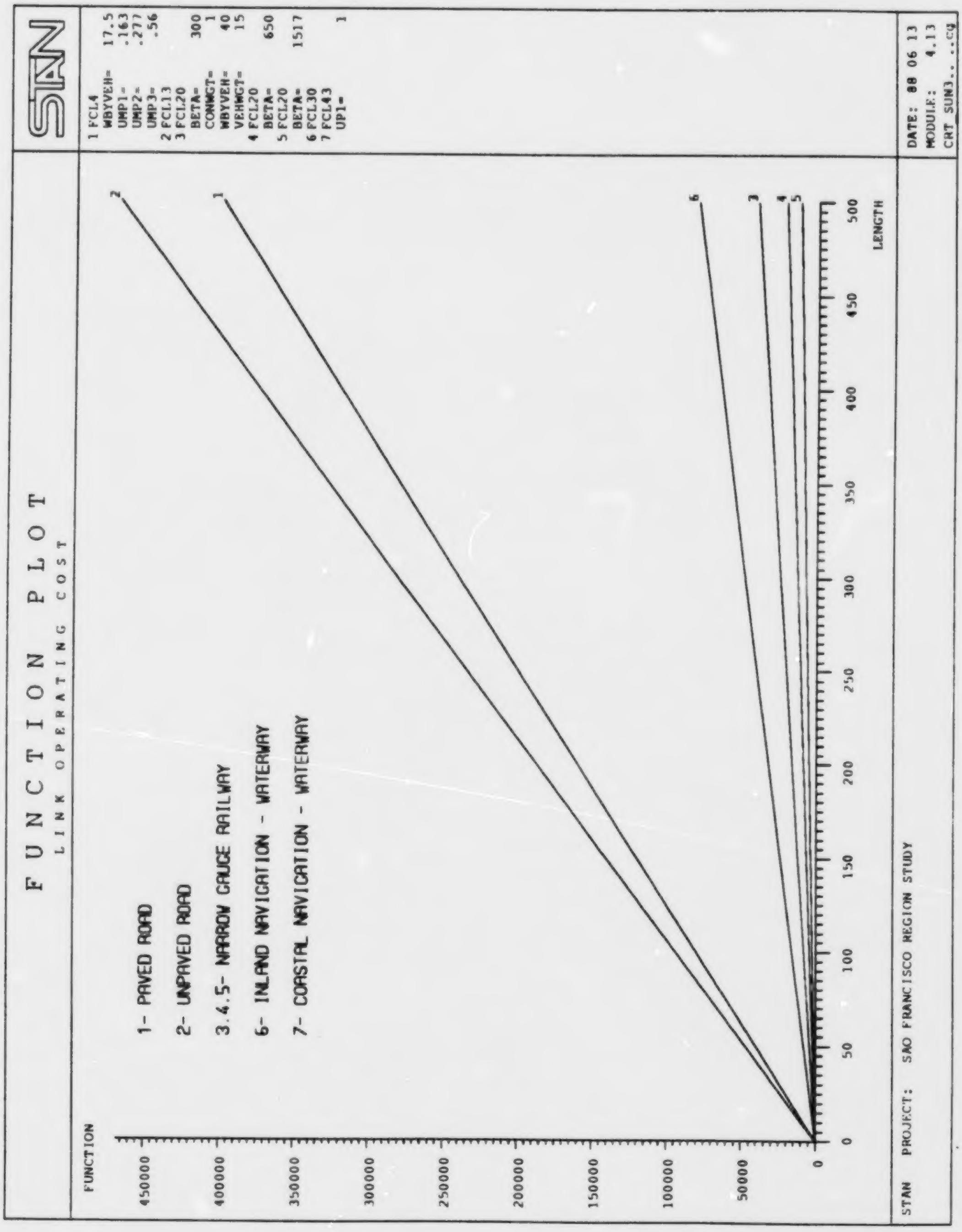


Figure 21 Salt Link Cost Functions

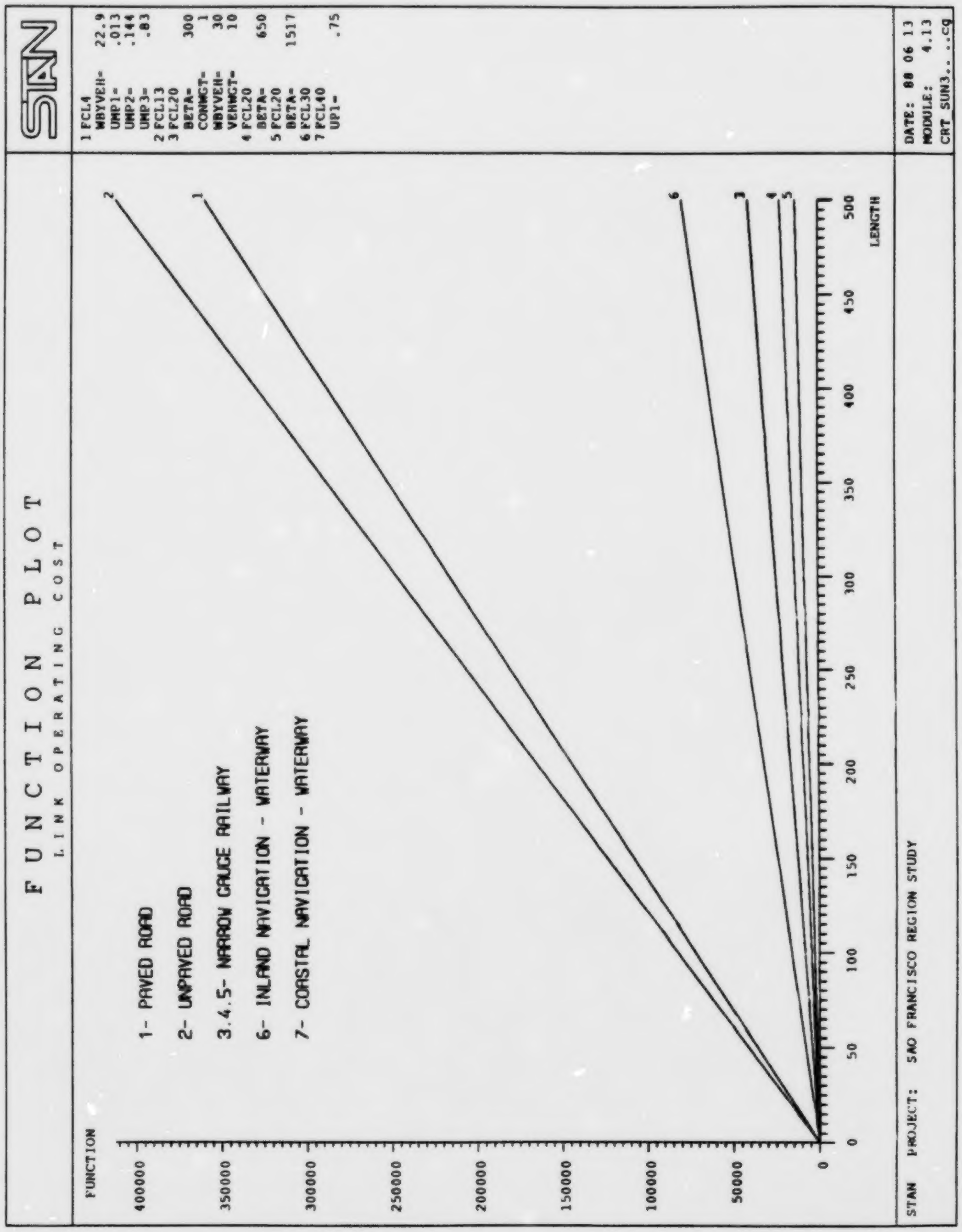


Figure 22 Agricultural Solid Bulk Link Cost Functions

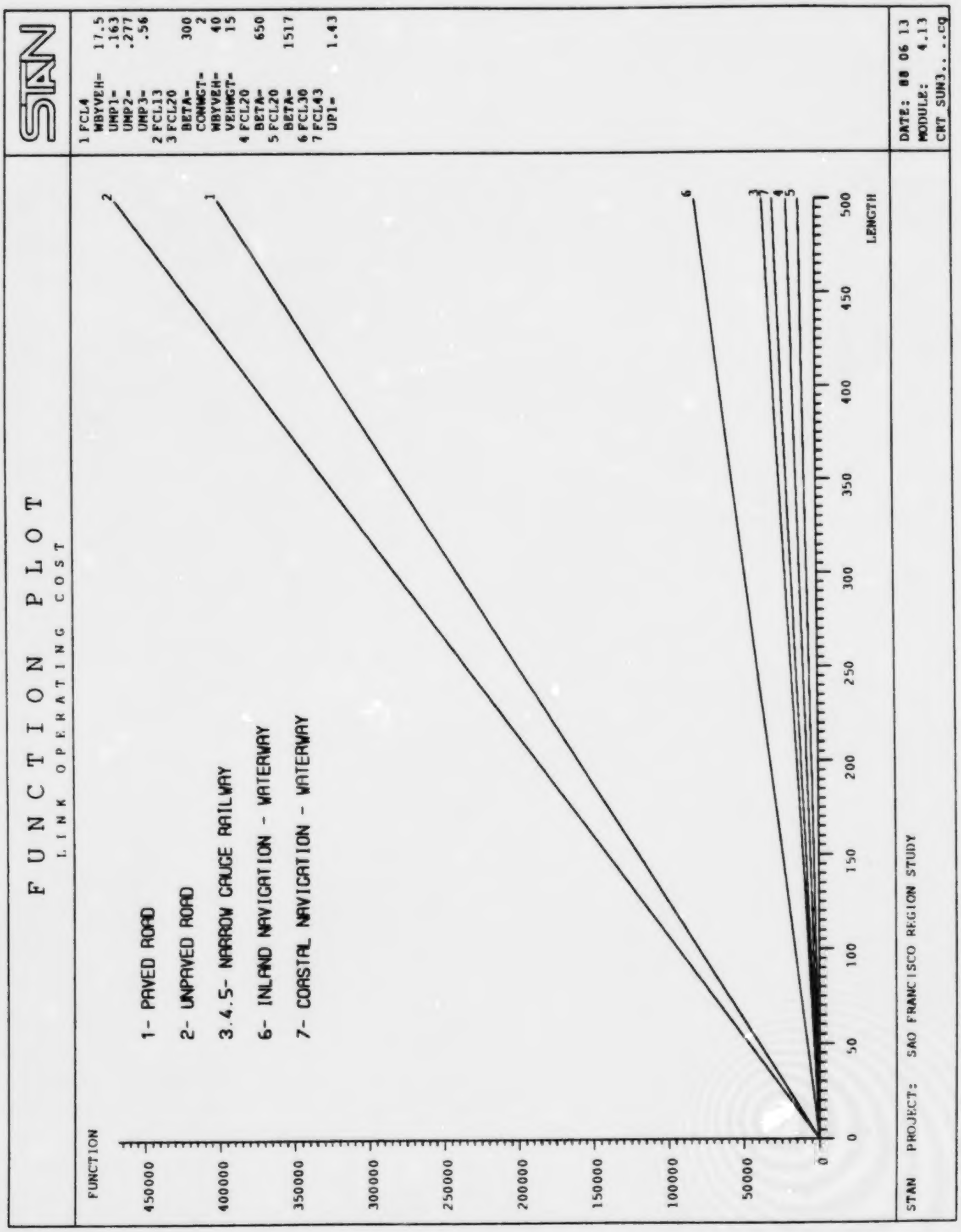


Figure 23 Cement Link Cost Functions

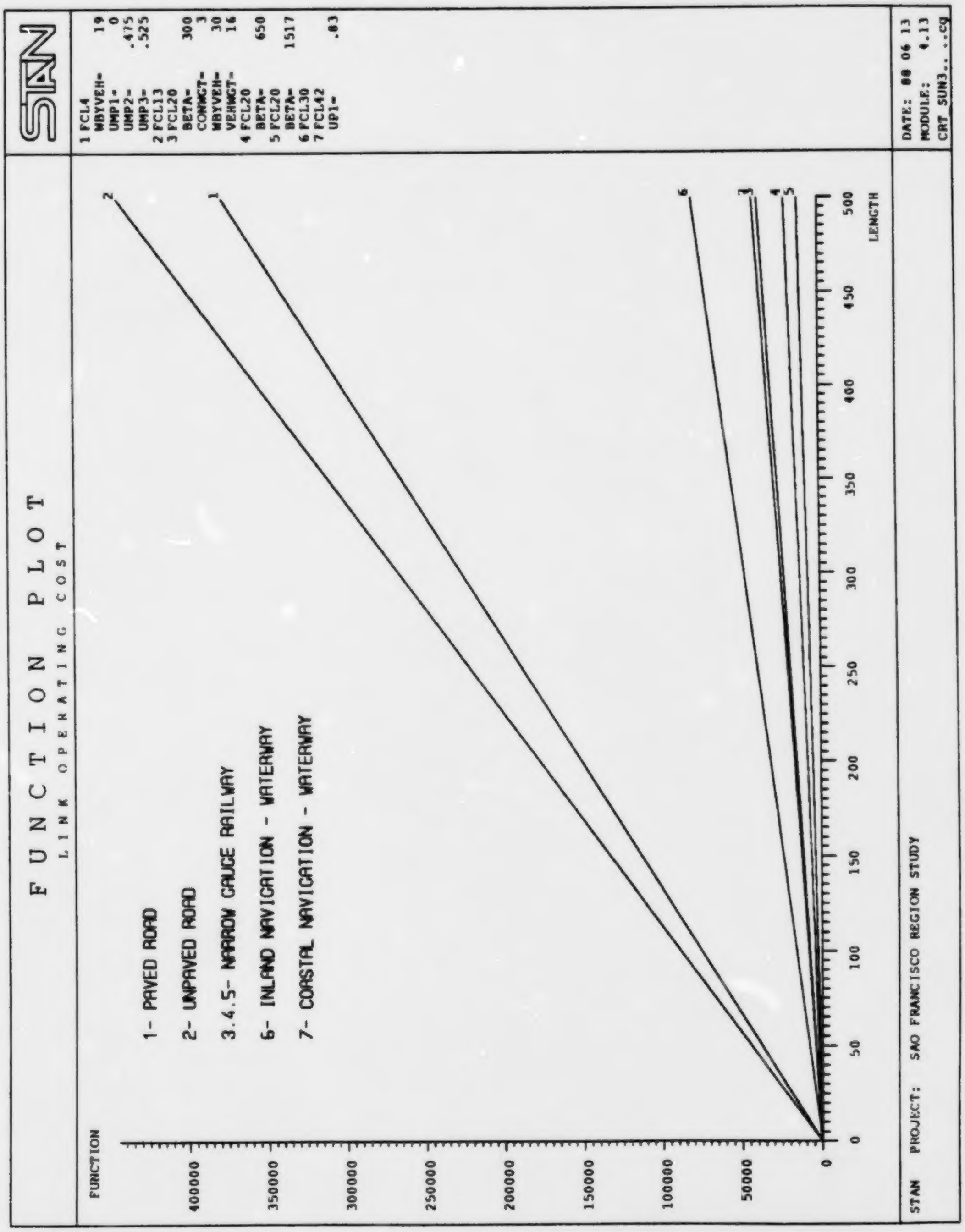


Figure 24 Petroleum Byproducts Link Cost Functions

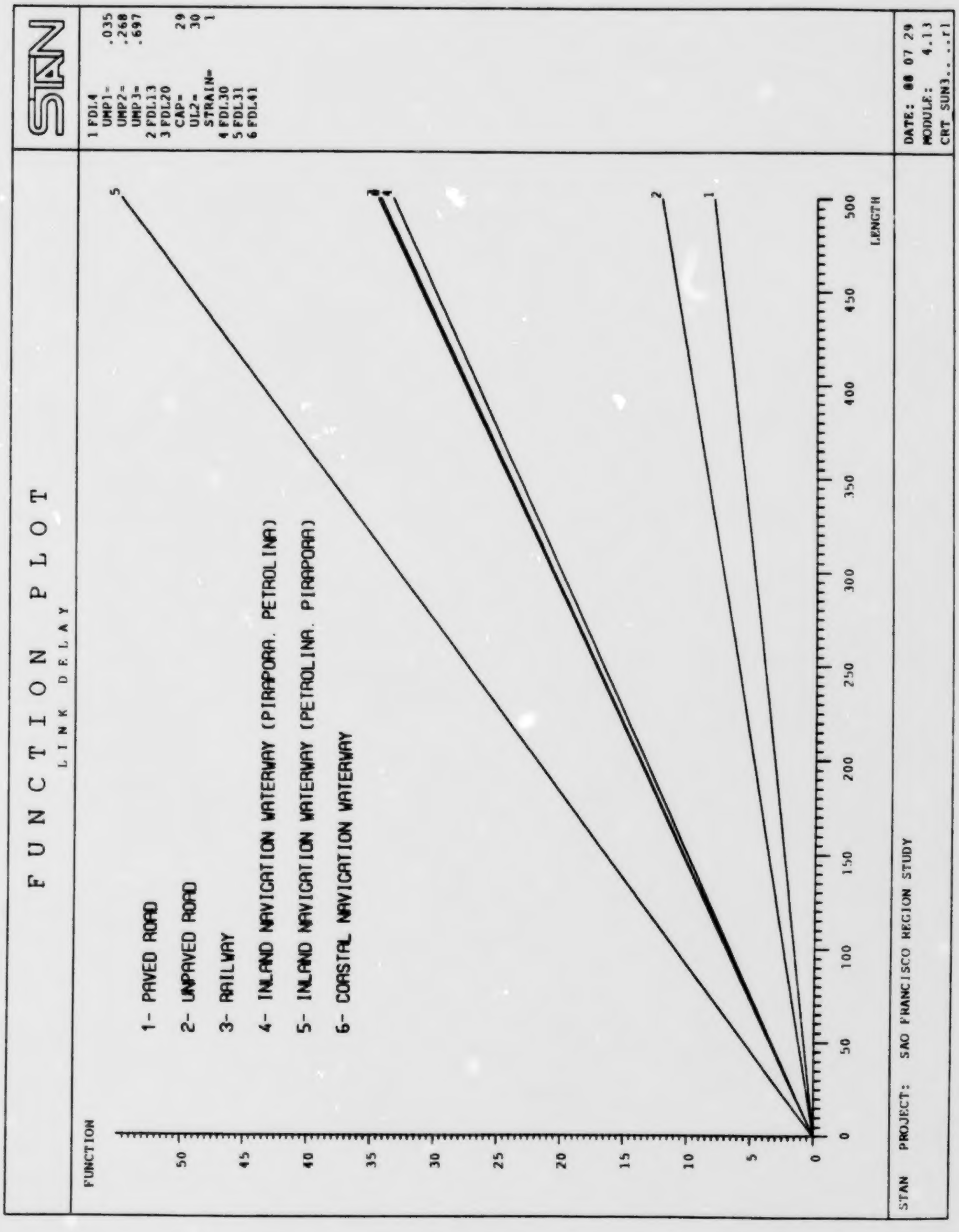


Figure 25 Gypsum Link Delay Functions

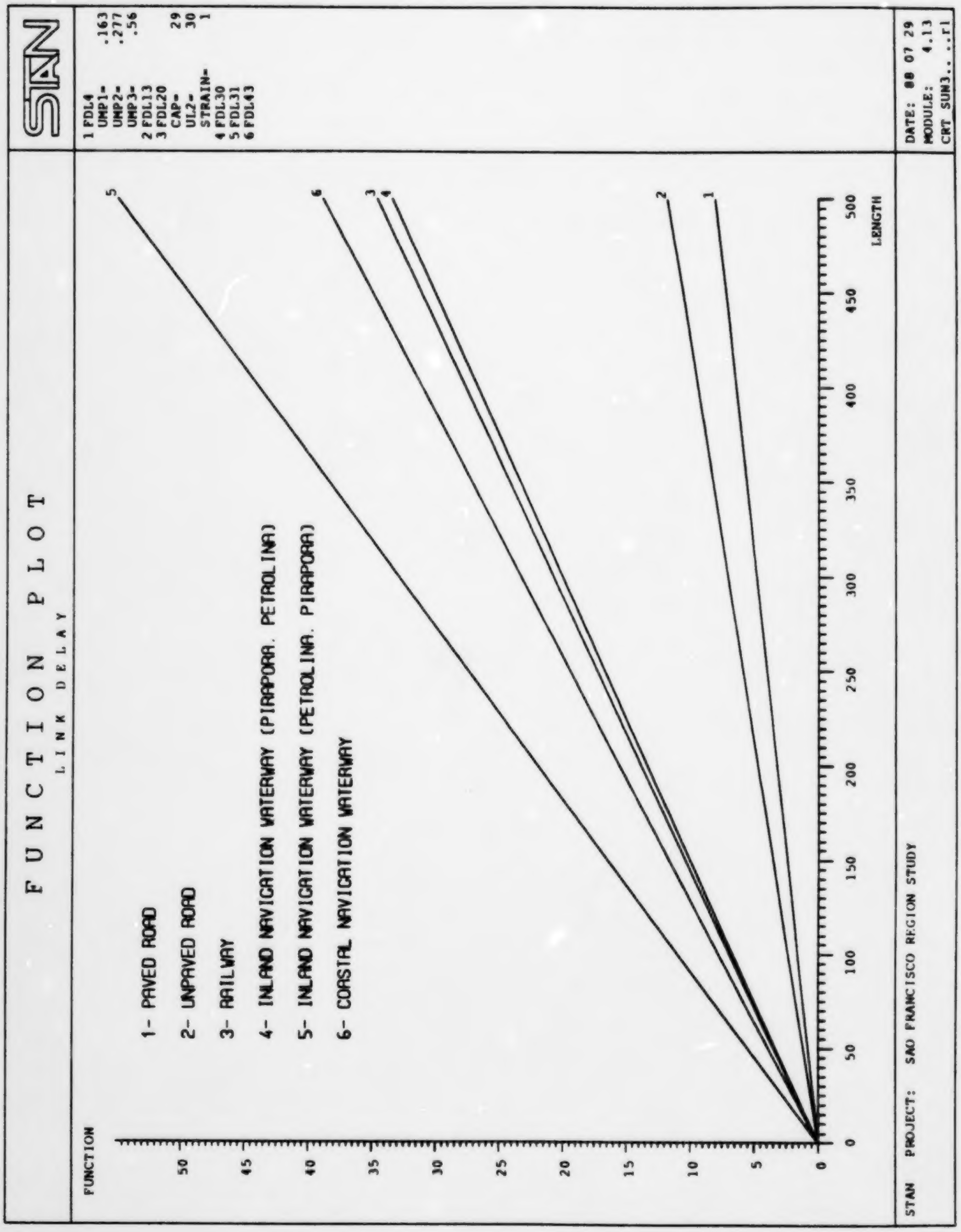


Figure 26 Salt Link Delay Functions

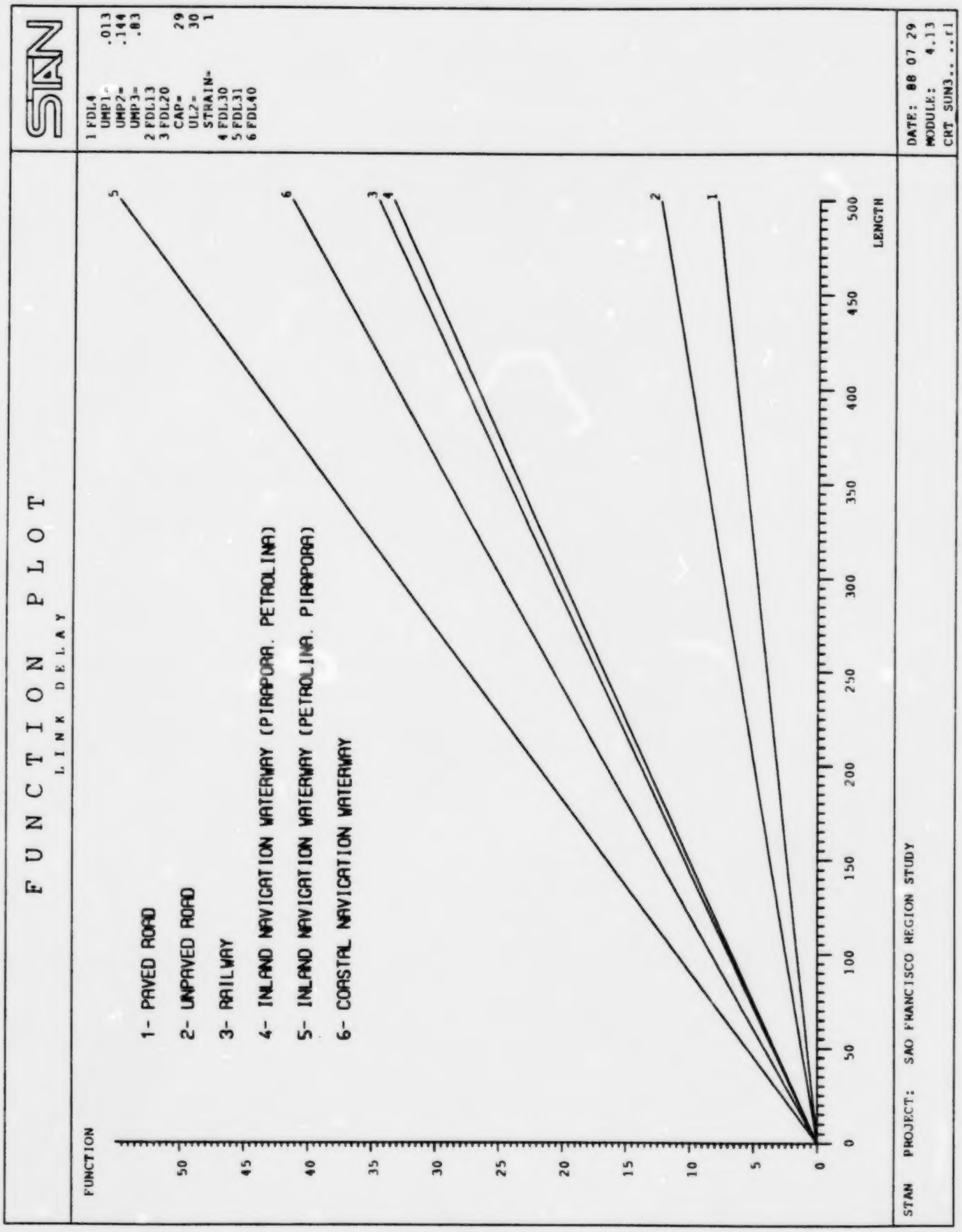


Figure 27 Agricultural Solid Bulk Link Delay Functions

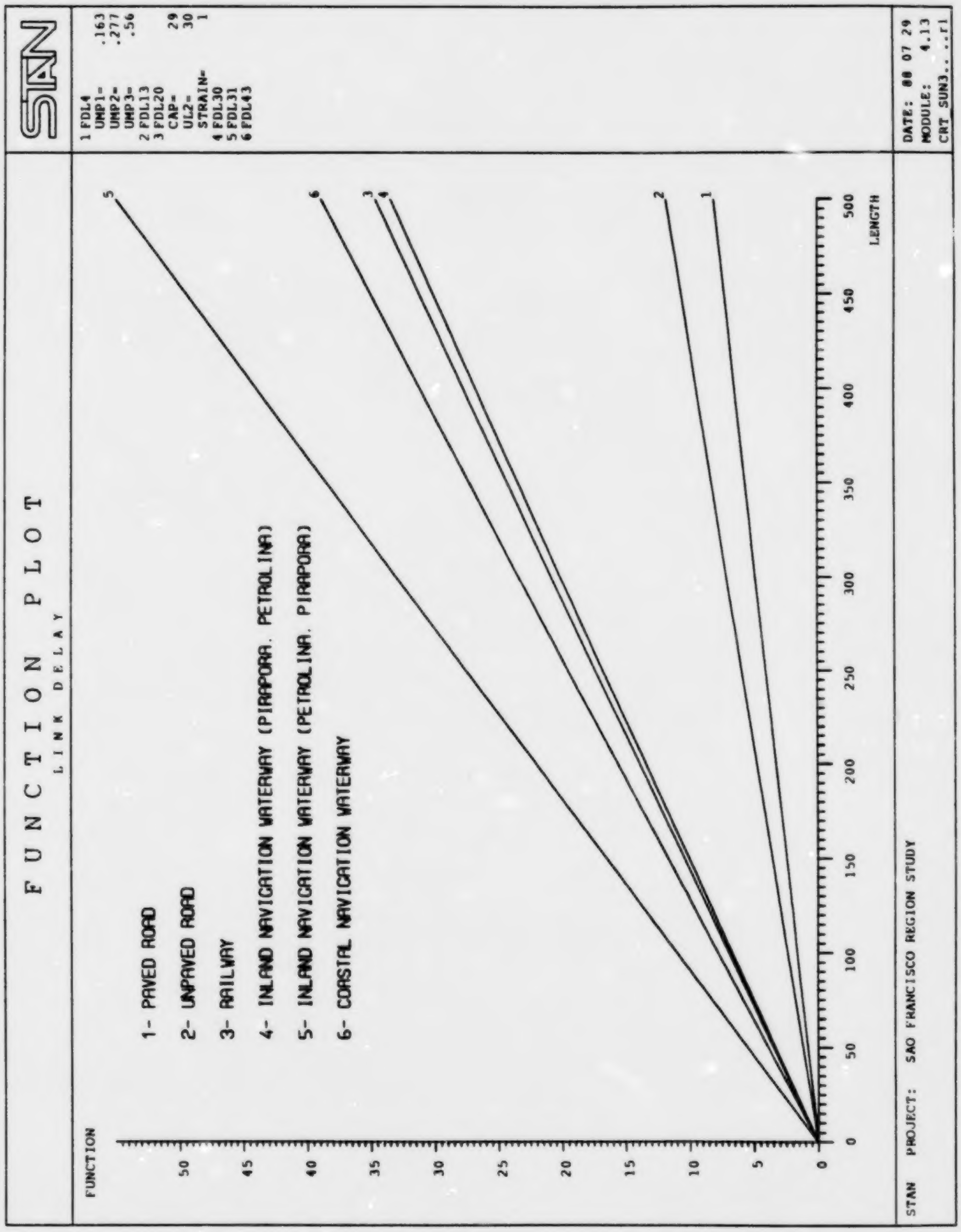


Figure 28 Cement Link Delay Functions

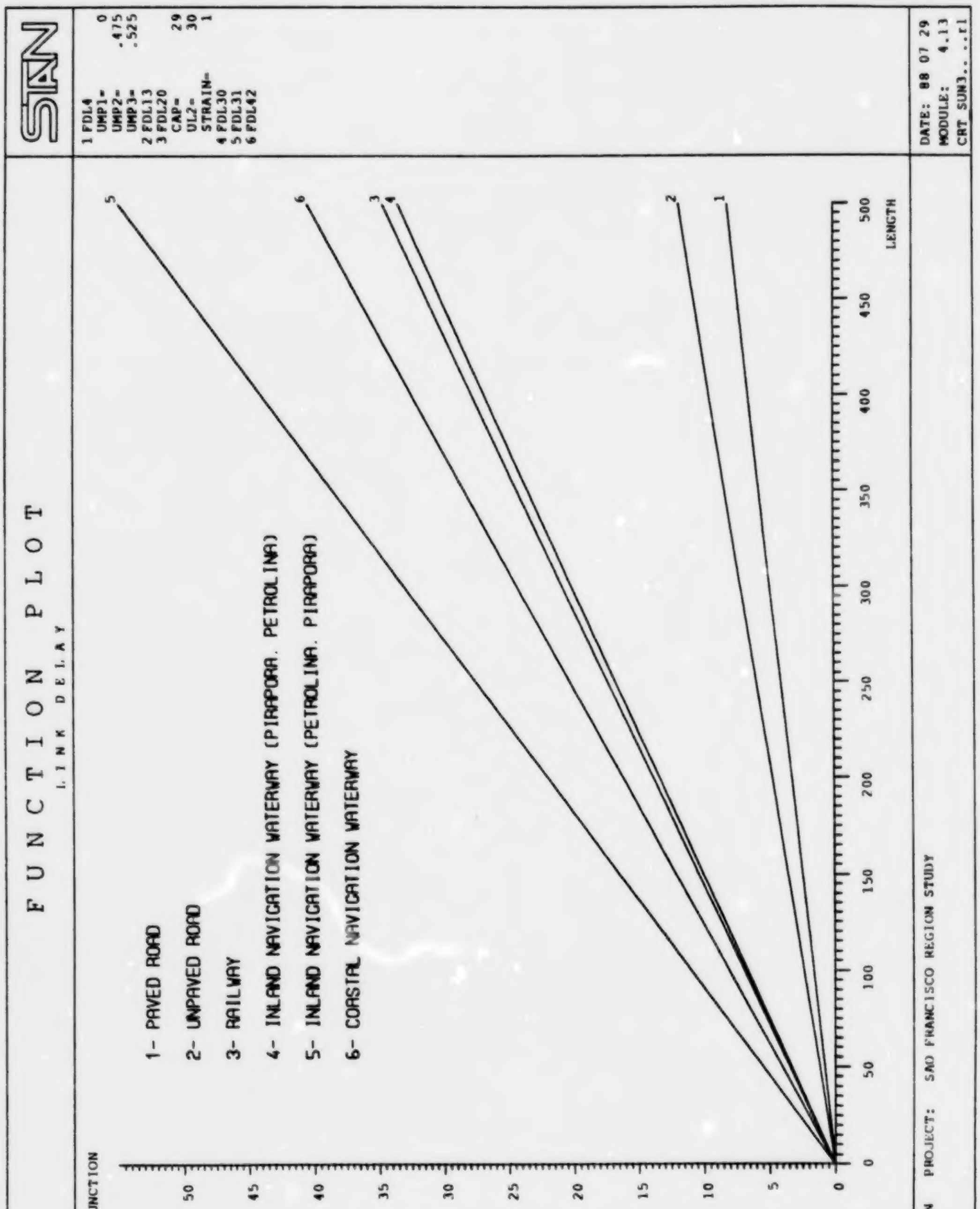


Figure 29 Petroleum Byproducts Link Delay Functions

3.2 ANALYSIS OF RESULTS

3.2.1 Definition of Scenarios

Six scenarios were defined for the São Francisco Corridor for analysis by the STAN system as follows: the transportation network with or without the Transnortheastern railway; the demand for 1987 or 1990; using the operating cost or the transportation time as assignment criterion (see Table 16). For the scenarios considering the Transnortheastern railway, only the projected demand for 1990 was used, since its period of construction is likely to exceed three years. No captive flows were identified for any product on any mode or mode combinations, thus allowing the modal split to be determined by the selection of the minimum impendance route during the assignment process.

Demand Supply	1987	1990
Current Situation	1000 (Cost)	3000 (Cost)
	2000 (Time)	4000 (Time)
With Transnortheastern Railway	-	5000 (Cost)
	-	6000 (Time)

Table 16 Scenario Specification

The number of interations of the multi-mode multi-product assignment algorithm depended upon the assignment criterion that was used. When operating costs were used, only one iteration was required, since the constant marginal value of the function implies an assignment of freight on the "minimum cost path" between each origin-destination pair. When time was the criterion, both congestion on the railway and the limited capacity of ports made for more complicated functions and additional iterations necessary to reach the solution. The solution was reached, in general, in less than ten iterations.

The freight assignment results will be presented in terms of utilization of the transportation system, including the transshipment facilities, for each product, by using plots and quantitative evaluations. Comparisons between the scenarios are also included in order to identify the redistribution of the transportation flows resulting from increased transportation demand for the products and from the construction of the Transnortheastern railway.

3.2.2 Analysis of the Current Transportation System

For the scenario reflecting the current situation, an analysis of the utilization of the transportation system shows different routes being used, depending upon the type of assignment criterion adopted (cost or time). On the other hand, since there were no structural changes in demand predicted between years 1987 and 1990, the flow distribution was not affected by the 16% demand increase; freight volume increased, but used the same routes.

Table 17 shows the aggregate results for the different demand scenarios: the total operating cost (Cr$) or time (h) and the associated total production (tons-km). The difference between the results for 1987 and 1990 corresponds only to the increase in demand, since the unit costs of Cz$ 0.13/t-km and 0.0184h/t-km remained constant in

Reference Year	Type of Assignment	Objective Value Cr$ or h	Production 10^3 t-km
1987	Cost	0.460235 x 10^{10}	35211514.4
	Time	0.487589 x 10^6	26448474.2
1990	Cost	0.532578 x 10^{10}	41222240.3
	Time	0.573897 x 10^6	31117389.1

Table 17 Assignment Results - Current Network

this period. Therefore, the 16% demande increase represented an addition of around Cr$ 0.724 x 10^9 to transportation cost and of 0.963 x 10^6 h to time, these values being very close to an equivalent increase of the total cost and time obtained in the base year scenario. It may also be noted that the selection of routes according to time lowers by some 30% the total tons-km travelled as compared to an assignment done according to cost: in both demand scenarios, the total transportation distance was reduced by making a larger utilization of the highway mode.

The type of assignment criterion also constituted a determining factor for the modal split, as shown in Table 18. For time assignments, the significant utilization of the highway mode reflected the higher speed of its vehicles, as compared to the other modes, and the smaller average transportation distance due to the accessibility of nodes by road. For operating cost assignments, one notes a broader mode utilization, with the railway system representing the basis for transportation, followed by coastal navigation. As to the required fleet, the estimates for the railway case indicate a maximum of 100 trains/year (by considering an average composition of 40 wagons) which is a value much smaller than the capacity of the rail sections in the transportation network of the area.

These freight volume estimates by mode are coherent with the variation intervals of the cost or delay by ton obtained for each mode, following the assignment process (see Figure 30). These intervals include the effects of the average transportation distance and of the different products. In the "time" scenario, intervals of modal competion were identified: between the narrow and the wide gauge railways and between unpaved roads and wide-gauge railways. On the same figure it is also possible to observe the highway-railway predominance when time was the decision criterion, and the railway-navigation predominance when the criterion was the operating cost. It is worth stressing that variation intervals, when single values are observed, indicate that the specific product does not influence it.

Figures 31 and 32 illustrate the utilization of the transportation system by the total freight volumes assigned to it, resulting for the cost and time scenarios, respectively. The superposition of these graphs shows the different utilization of routes as a function of the assignment criterion adopted. In fact, there are alternatives for each mode to meet the needs of the long-distance traffic on the North East-Center South axis. The location of the transportation demand also influences the selection of these routes. Modal integration, which is still very expensive, does not allow these routes to complement each other; this is also due to the fact that not all modes have access to all demand. Graphs for the year 1990 are not presented, since they display the same utilization of the system.

When operating cost is used as an assignment criteria, the inter-corridor flows were channeled to the ports and coastal navigation modes, the railway system was used

Mode	1987		1990	
	Cost	Time	Cost	Time
Paved Road (p)	5796.2 (284)	181750.1 (9781)	6326.1 (310)	212189.0 (11423)
Unpaved Road (t)	75.4 (4)	2148.3 (115)	73.5 (4)	2525.7 (135)
Narrow-gauge Railway (e)	148882.5 (681)	60.9 (2)	46184.1 (1298)	768.7 (22)
Wide-gauge Railway (l)	2504.9 (69)	707.9 (20)	172066.6 (5074)	-
Inland-navigation Waterway (h)	212.9 (1)	1.1 (-)	261.1 (1)	4.5 (-)
Coastal-navigation Waterway (c)	39734.1 (7)	-	47465.7 (8)	-

Note: The values between parentheses are the required number of vehicles to meet demand.

Table 18 Mode Utilization - Current Network

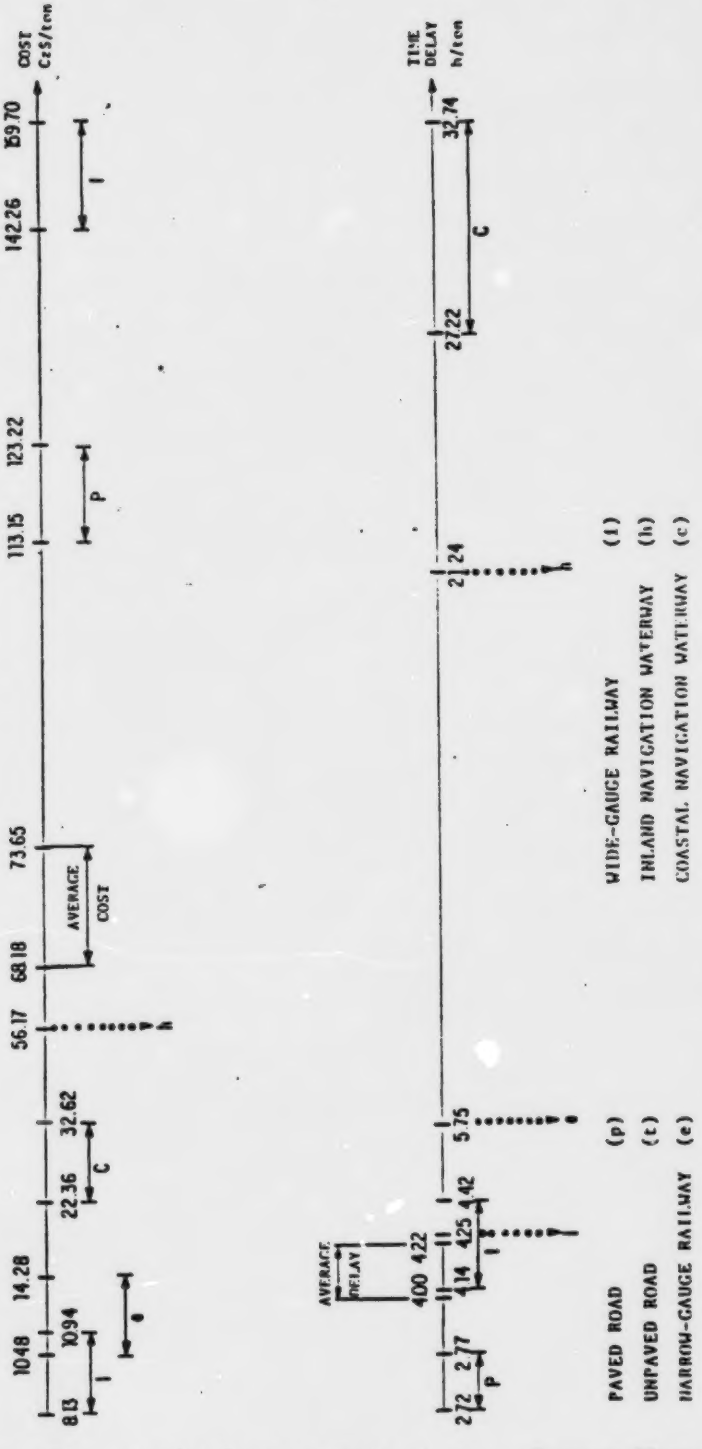
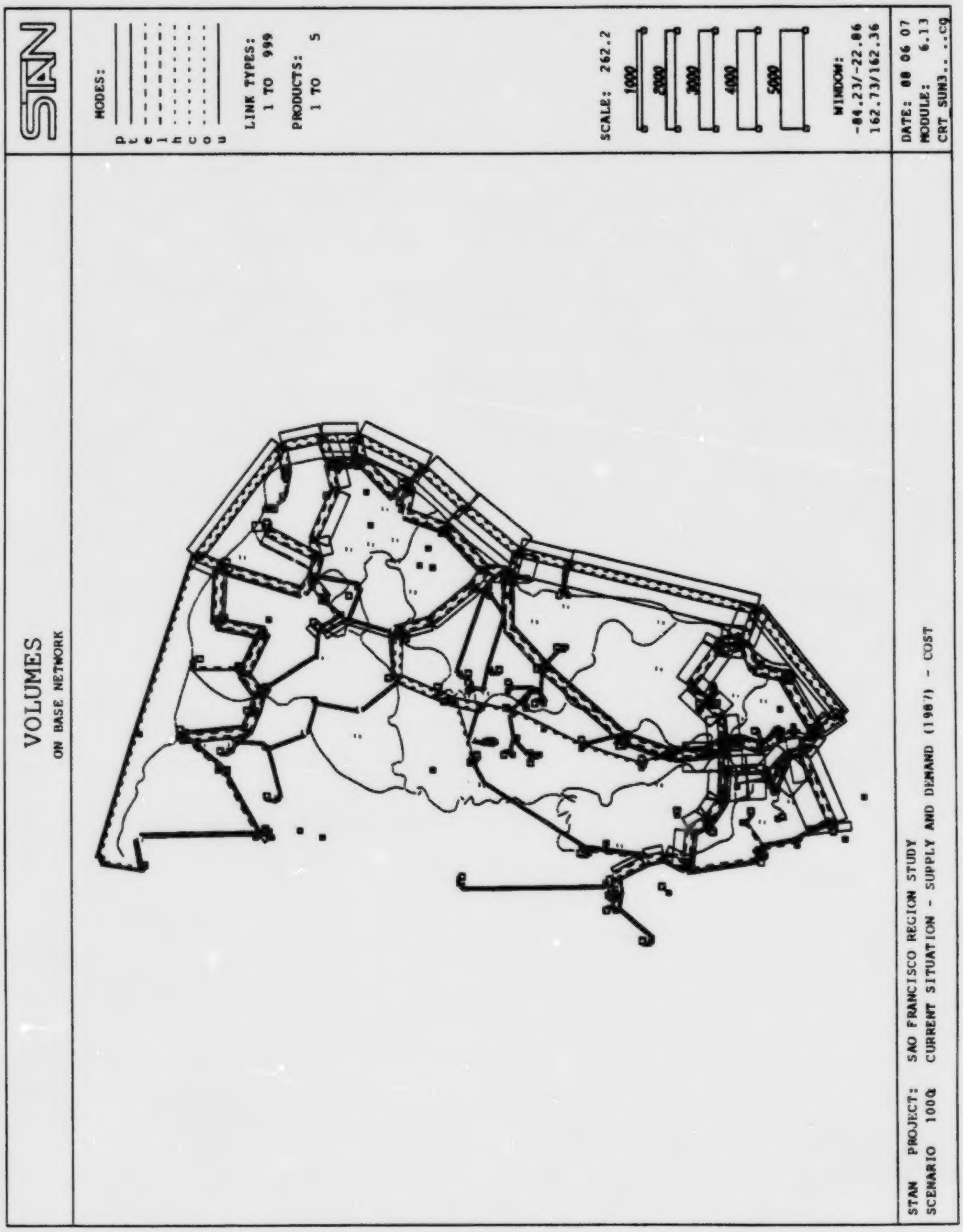

COST Cz$/ton
8.13
10.48
10.94
14.28
22.36
32.62
56.17
68.18
73.65
113.15
123.22
142.26
159.70
AVERAGE COST
TIME DELAY h/ton
2.72
2.77
4.00
4.14
4.22
4.25
4.42
5.75
21.24
27.22
32.74
AVERAGE DELAY
p
t
e
c
l
h
PAVED ROAD (p)
UNPAVED ROAD (t)
NARROW-GAUGE RAILWAY (e)
WIDE-GAUGE RAILWAY (l)
INLAND NAVIGATION WATERWAY (h)
COASTAL NAVIGATION WATERWAY (c)

Figure 30 Modal Cost and Delay by ton - Current Network


STAN
MODES:
p
t
e
l
h
c
o
u
LINK TYPES:
1 TO 999
PRODUCTS:
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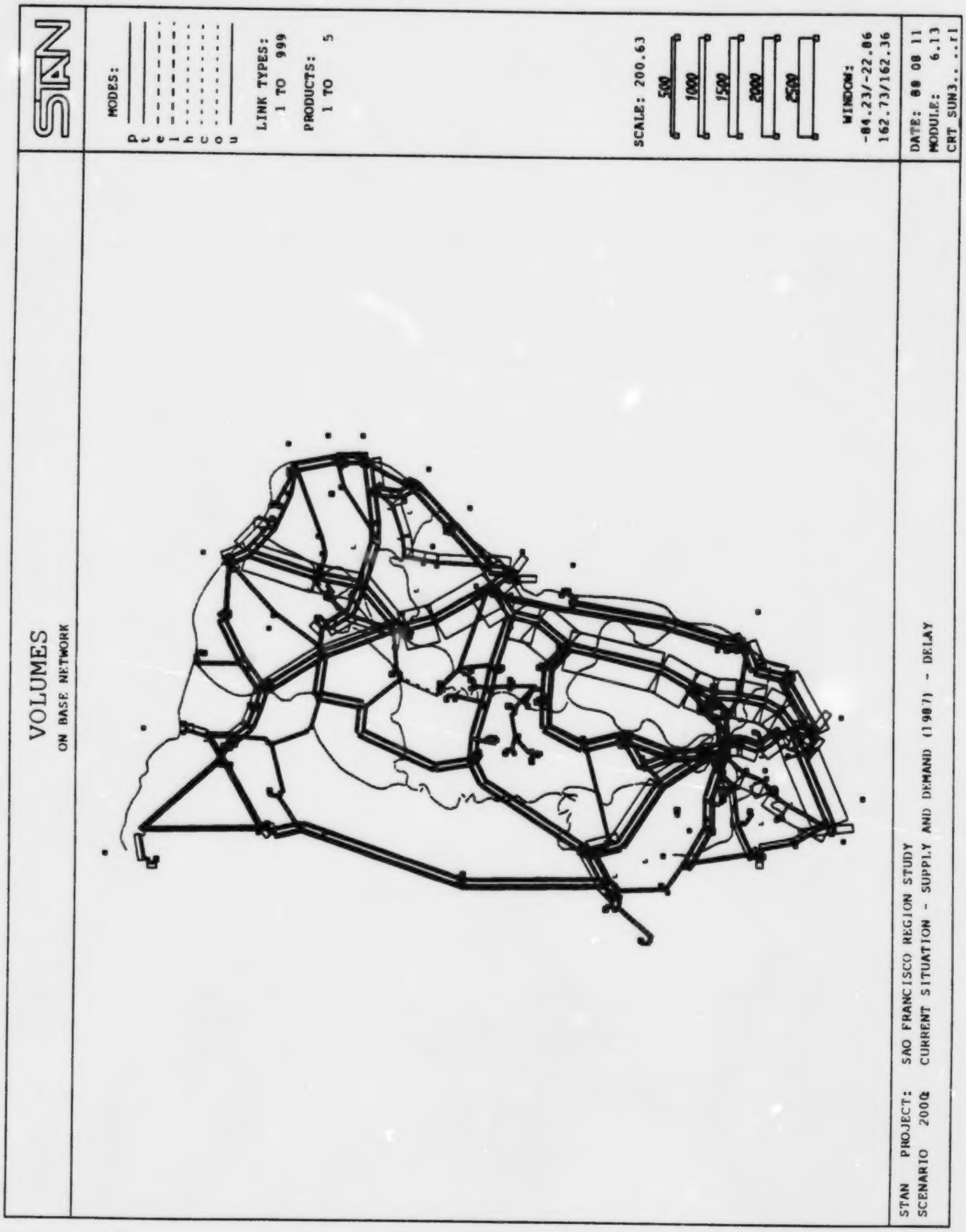
2000
3000
4000
5000
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 07
MODULE: 6.13
CRT SUN3.. ..cg
VOLUMES
ON BASE NETWORK
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100G CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST

Figure 31 Cost Assignment - 1987 Situation


VOLUMES
ON BASE NETWORK
STAN
MODES:
p
t
e
l
h
c
o
u
LINK TYPES:
1 TO 999
PRODUCTS:
1 TO 5
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2500
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 08 11
MODULE: 6.13
CRT SUN3.. ..r1
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 200Q CURRENT SITUATION - SUPPLY AND DEMAND (1987) - DELAY

Figure 32 Delay Assignment - 1987 Situation

to move freight toward the interior, while the highway complemented the access to the supply and demand centers. In this scenario, the utilization of the São Francisco waterway was complementary to the railway system for import and export flows and was integrated to the highway system for the internal flows. It is noteworthy that the location of most of the demand centers near the coastline favored coastal navigation, which also has a unit cost (per t-km) lower than the other modes.

When time was the decision criterion, the use of the highway system is significant (it also identifies alternative transportation axes), except for the railway flows within the Southeast region and the waterway flows between the ports of Xique-Xique and Bom Jesus da Lapa. Coastal navigation was not used, since transshipment times in ports were too important and the ship speeds too low. Economies of scale resulting from ship capacity were not being considered.

Here are some observations particular to the selected products:

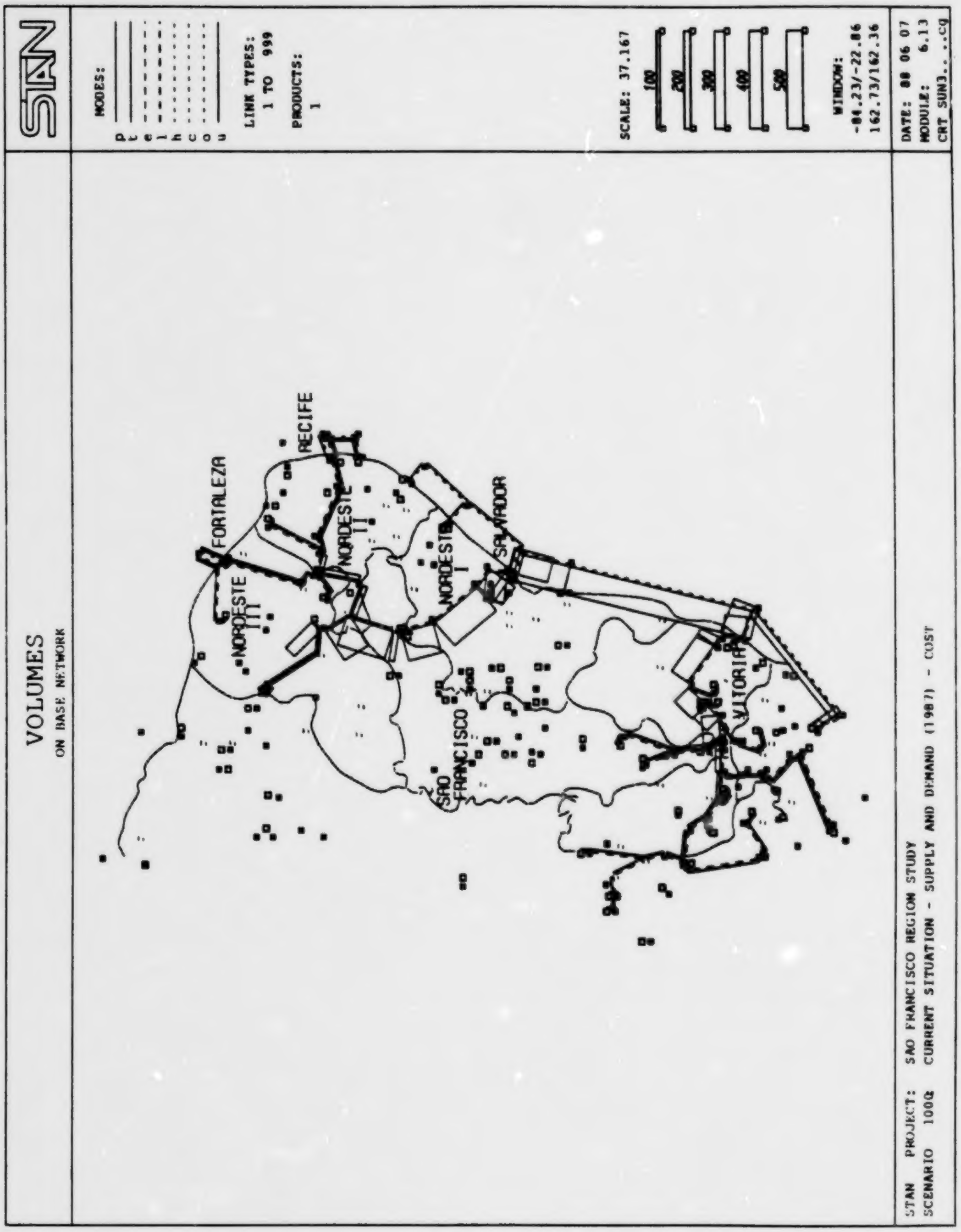
- In the cost scenario, gypsum and salt were moved through the highway-railway system to the Northeast region and by coastal navigation to the ports on the South-East region, from where the highway-railway system was used for distribution (see Figures 33 and 34). When time was considered, transportation mostly used the road BR-116, parallelling the coastline, and connected to transversal roads in the North-East and Center-South regions (see Figures 35 and 36);
- Considering operating costs, the agricultural solid bulks were transported by the railway and the São Francisco river (see Figure 37). As to the time based assignment, the sections of the road network of the production region were used, the BR-153 route connecting Belém to Brasilia and BR-040 and the BR-262 route, used to supply the South-East region (see Figure 38);

- Cement used the railway-waterway system in the area of influence of the São Francisco Corridor, when operating cost was considered, and the highway system exclusively, when time was considered (see Figure 39 and 40). For the first scenario, the supplying of Belém through coastal navigation starting from the ports in the North-East region, is worth mentioning. One also notes significant flows within the South-East region;

- For petroleum byproducts and alcohol, the distribution of flows is similar to that of gypsum and salt, considering that the production centers are on the coastline: while in the cost scenario coastal navigation was used for the long-distance traffic, with the highway and railway systems moving freight toward the interior, in the time scenario there was only road transportation (see Figures 41 and 42).

Finally, modal interchanges were also analyzed. Tables 19 and 20 show the total volumes transshipped between the different combinations of modes in the cost and time scenarios respectively. More substantial exchanges are observed when cost is the decision criterion. The projected demand in the 1987-1990 period also showed a proportional increase in the volumes transshipped. While for the cost based scenarios, the use of the narrow-gauge railway mode ranged from 25% to 40% of the total volume moved (it predominates the combination with the wide-gauge subsystem and with coastal navigation), for the time based scenarios most transshipments were between paved roads and the subsystem of unpaved roads and the narrow-gauge railway. The ports on the São Francisco river handled volumes much below their capacities, reaching a maximum of 40 000 tons/year.

Figures 43 and 44 illustrate freight transfers, for the cost and delay based scenario respectively, at the following locations: Pirapora (1496), Petrolina (1792), Salgueiro (2006) and Ingazeira (2302). In the cost based scenario, the volume transferred from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MODES:
p
t
e
l
h
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o
u
LINK TYPES:
1 TO 999
PRODUCTS:
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SCALE: 37.167
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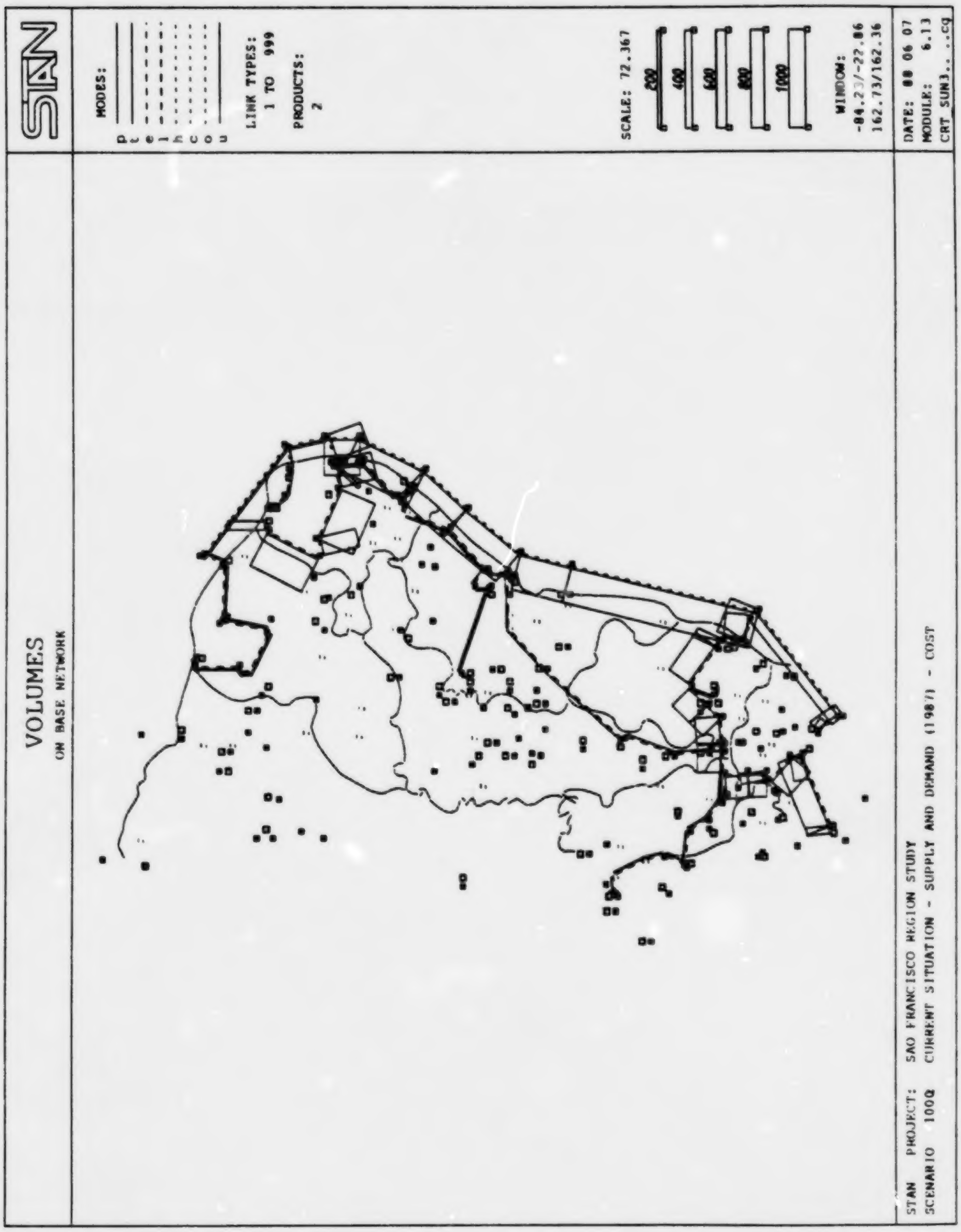
400
500
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 07
MODULE: 6.13
CRT SUN3...cg
VOLUMES
ON BASE NETWORK
FORTALEZA
RECIFE
NORDESTE II
NORDESTE I
SALVADOR
NORDESTE III
SAO FRANCISCO
VITORIA
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100G CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST

Figure 33 Gypsum Transportation - Cost on Current Network


STAN
VOLUMES
ON BASE NETWORK
MODES:
p
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e
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h
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o
u
LINK TYPES:
1 TO 999
PRODUCTS:
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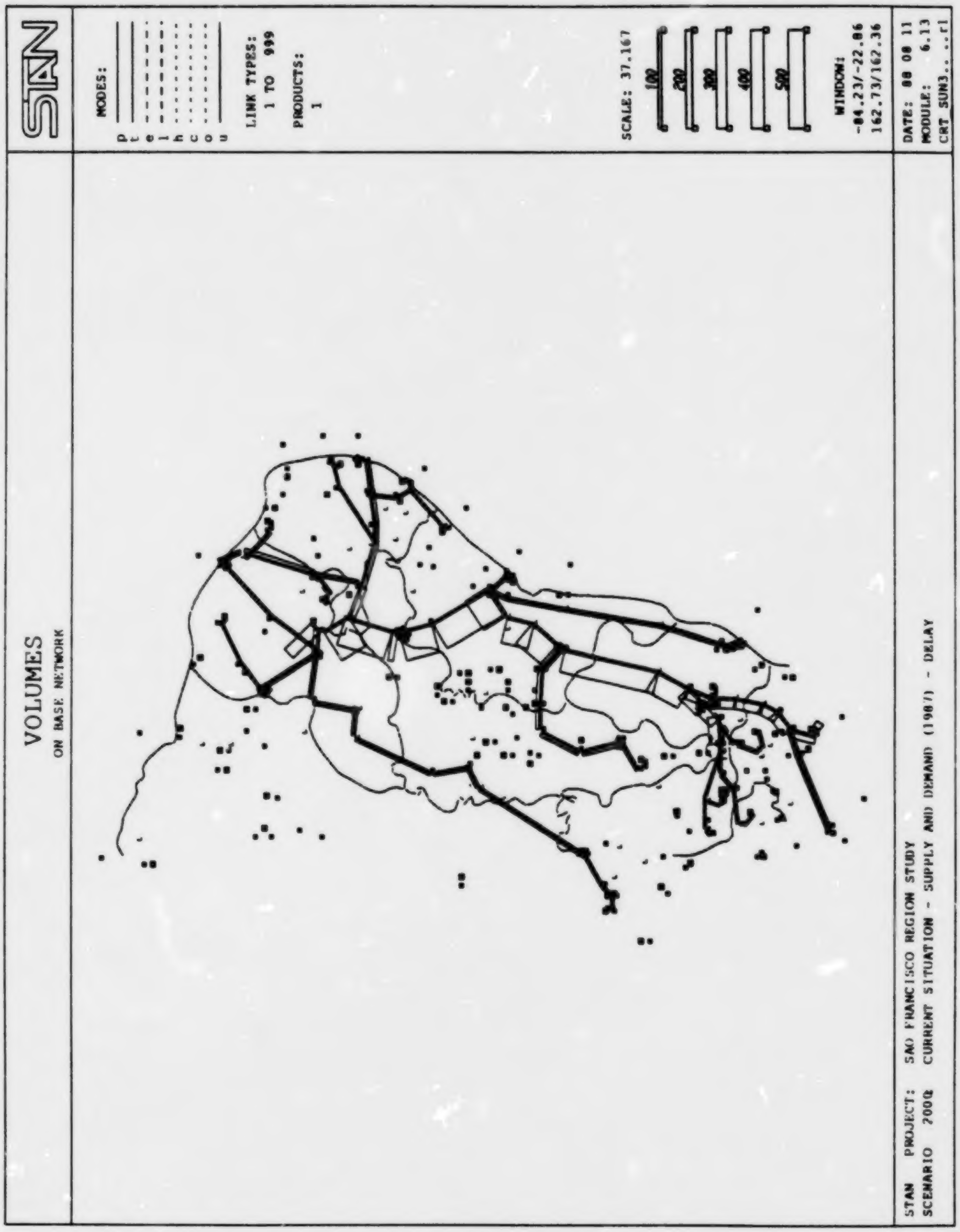
800
1000
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 07
MODULE: 6.13
CRT SUN3.. ..cg
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 1000 CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST

Figure 34 Salt Transportation - Cost on Current Network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u
LINK TYPES:
1 TO 999
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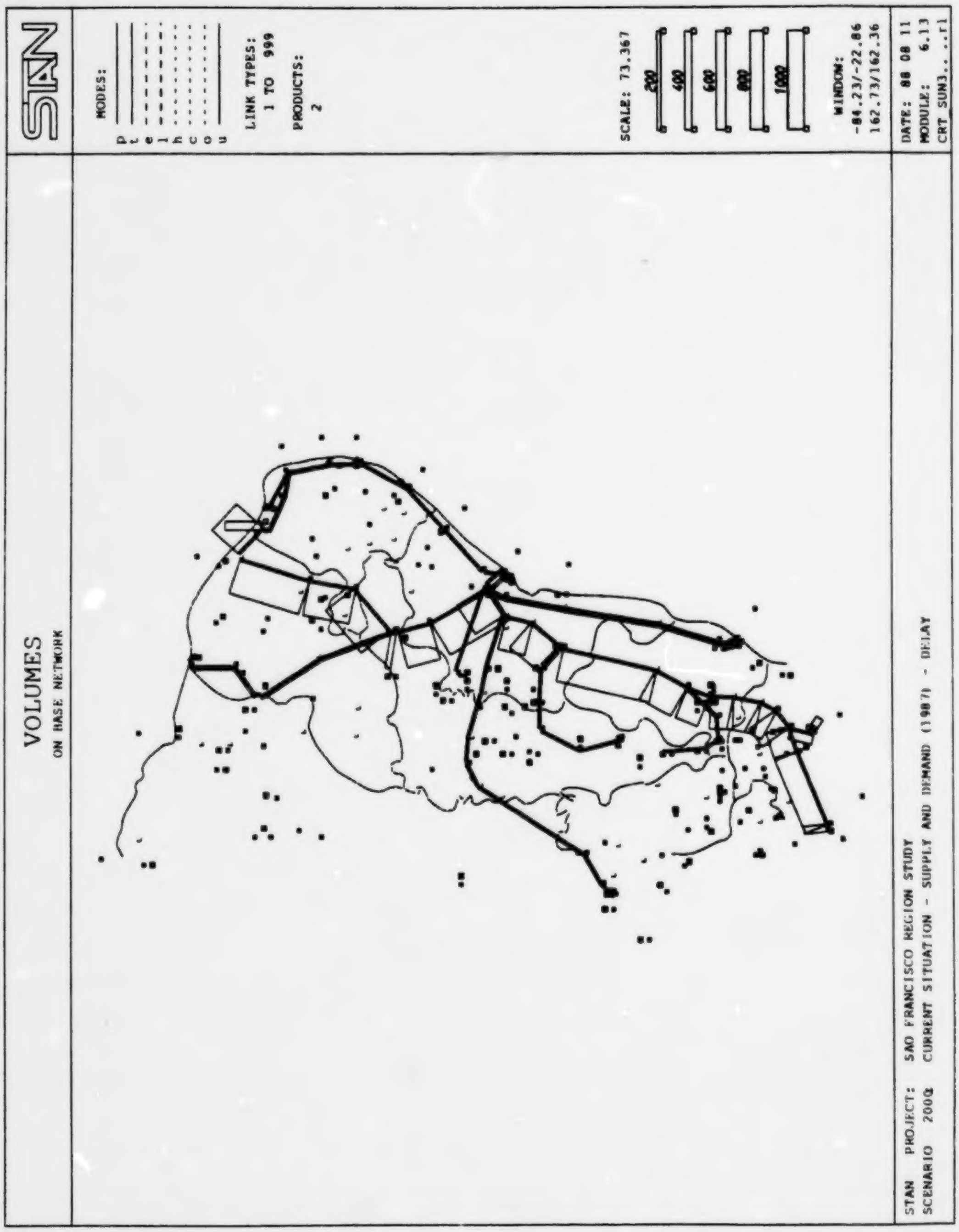
SCALE: 37.167
100
200
300
400
500
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 08 11
MODULE: 6.13
CRT SUN3... ...rl
VOLUMES
ON BASE NETWORK
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 2000 CURRENT SITUATION - SUPPLY AND DEMAND (1987) - DELAY

Figure 35 Gypsum Transportation - Delay on Current Network


VOLUMES
ON BASE NETWORK
STAN
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LINK TYPES:
1 TO 999
PRODUCTS:
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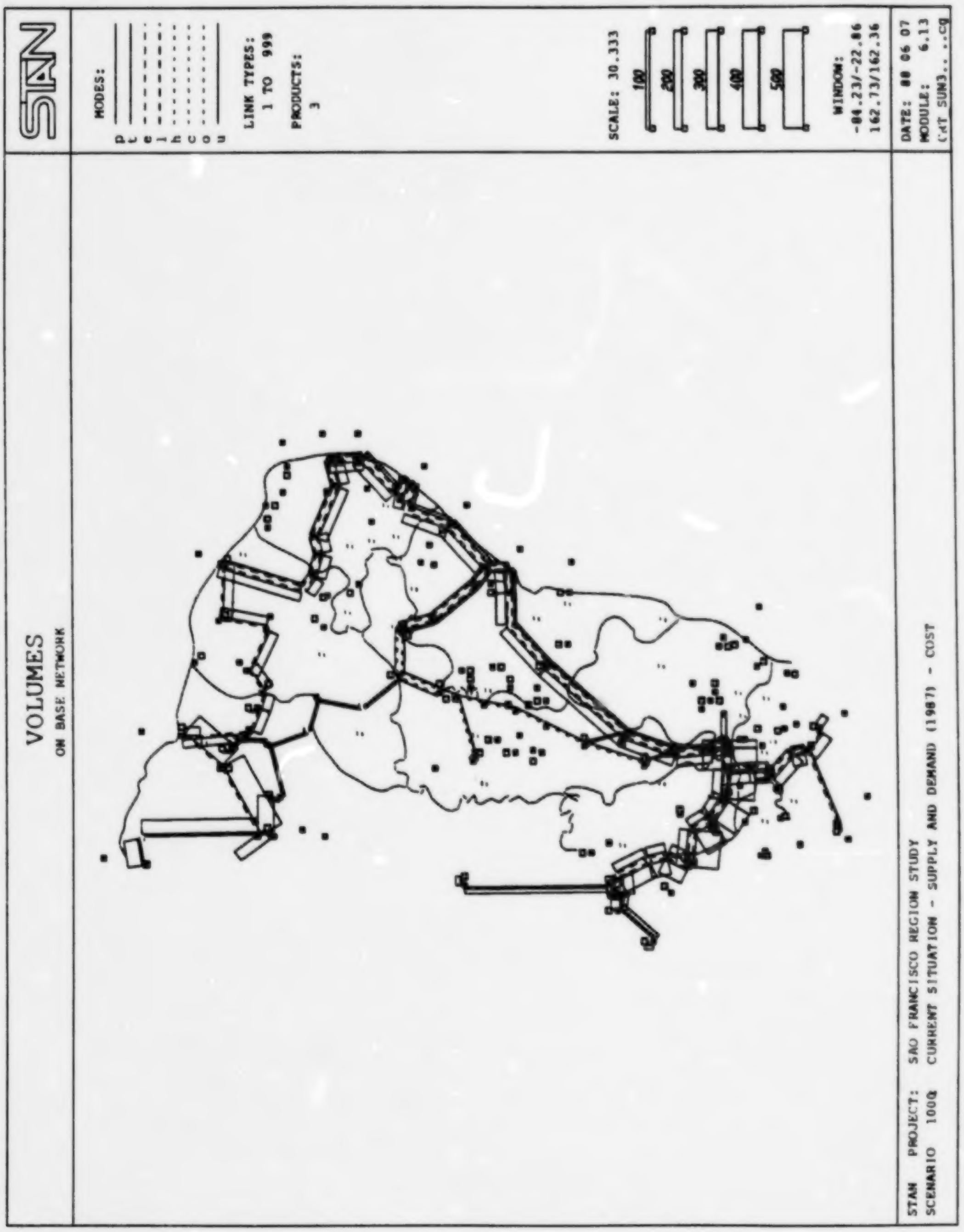
200
400
600
800
1000
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 08 11
MODULE: 6.13
CRT SUN3... ..rl
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 2000 CURRENT SITUATION - SUPPLY AND DEMAND (1987) - DELAY

Figure 36 Salt Transportation - Delay on Current Network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WINDOW:
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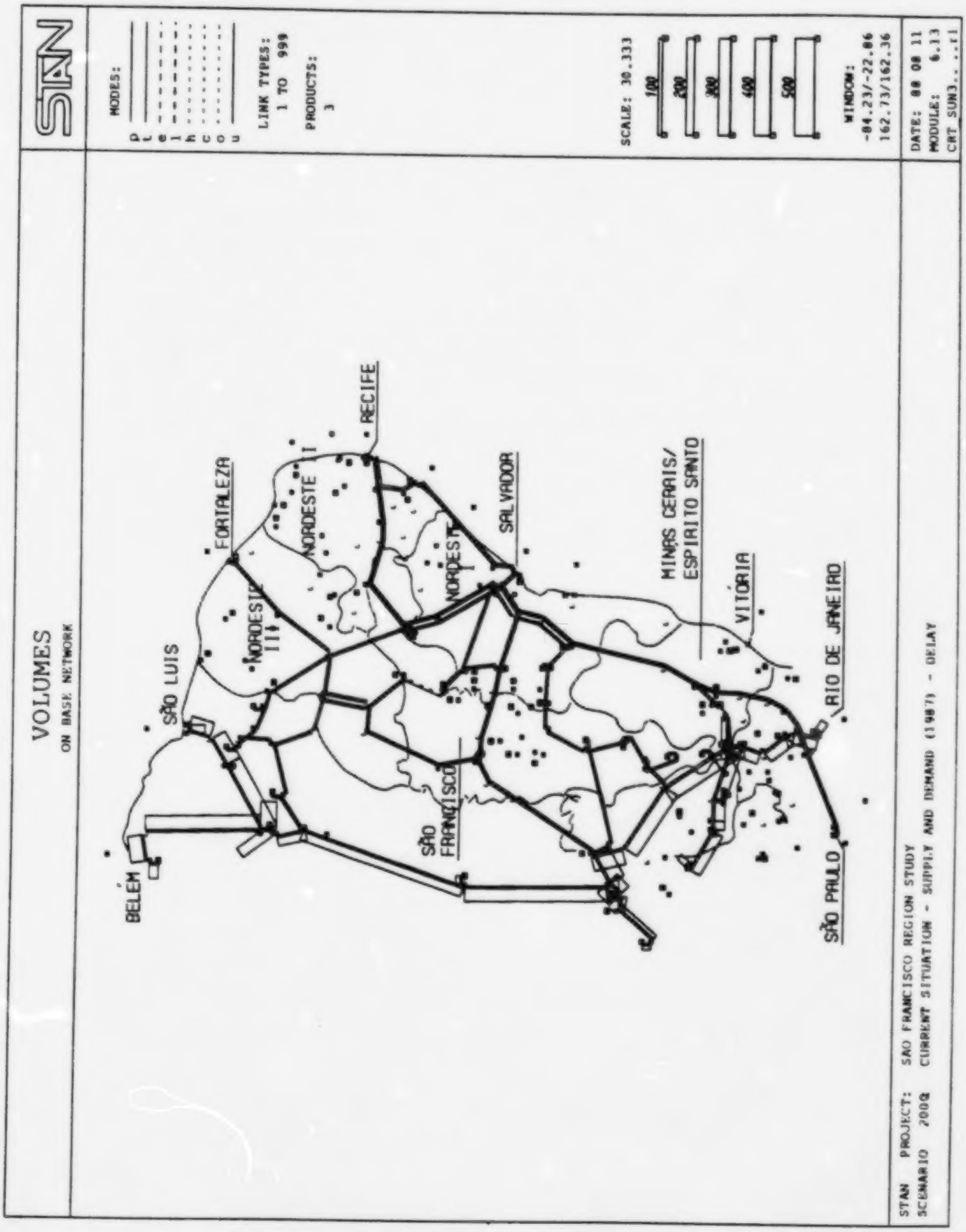
162.73/162.36
DATE: 88 06 07
MODULE: 6.13
C:T SUN3.. ..cg
VOLUMES
ON BASE NETWORK
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100Q CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST

Figure 37 Agricultural Solid Bulks - Cost on Current Network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o
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LINK TYPES:
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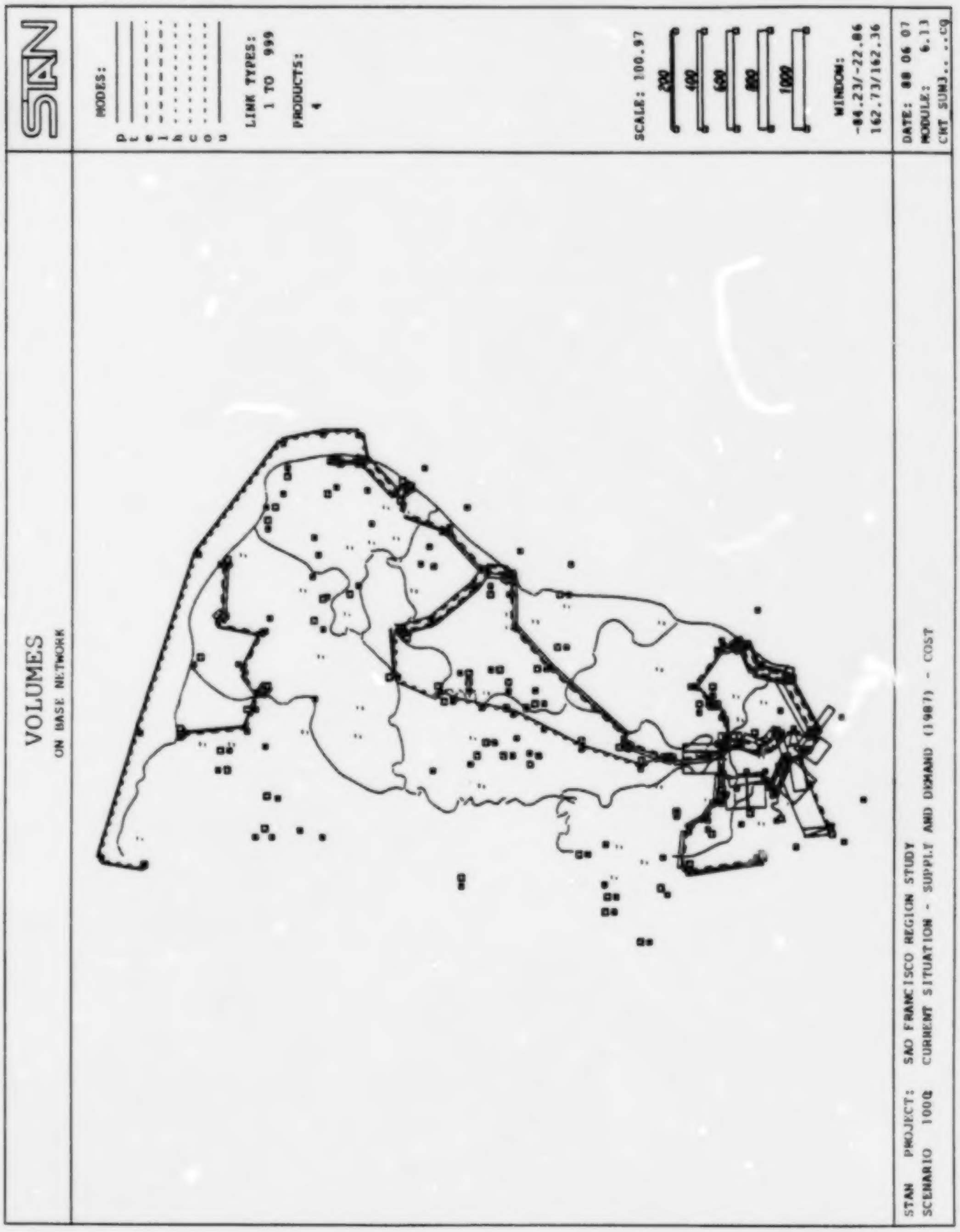
-84.23/-22.86
162.73/162.36
DATE: 88 08 11
MODULE: 6.13
CRT SUN3.. ..r1
BELÉM
SÃO LUIS
FORTALEZA
NORDESTE III
NORDESTE I
NORDESTE
RECIFE
SALVADOR
SÃO FRANCISCO
MINAS GERAIS/ ESPIRITO SANTO
VITÓRIA
RIO DE JANEIRO
SÃO PAULO
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 200Q CURRENT SITUATION - SUPPLY AND DEMAND (1987) - DELAY

Figure 38 Agricultural Solid Bulks - Delay on Current Network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LINK TYPES:
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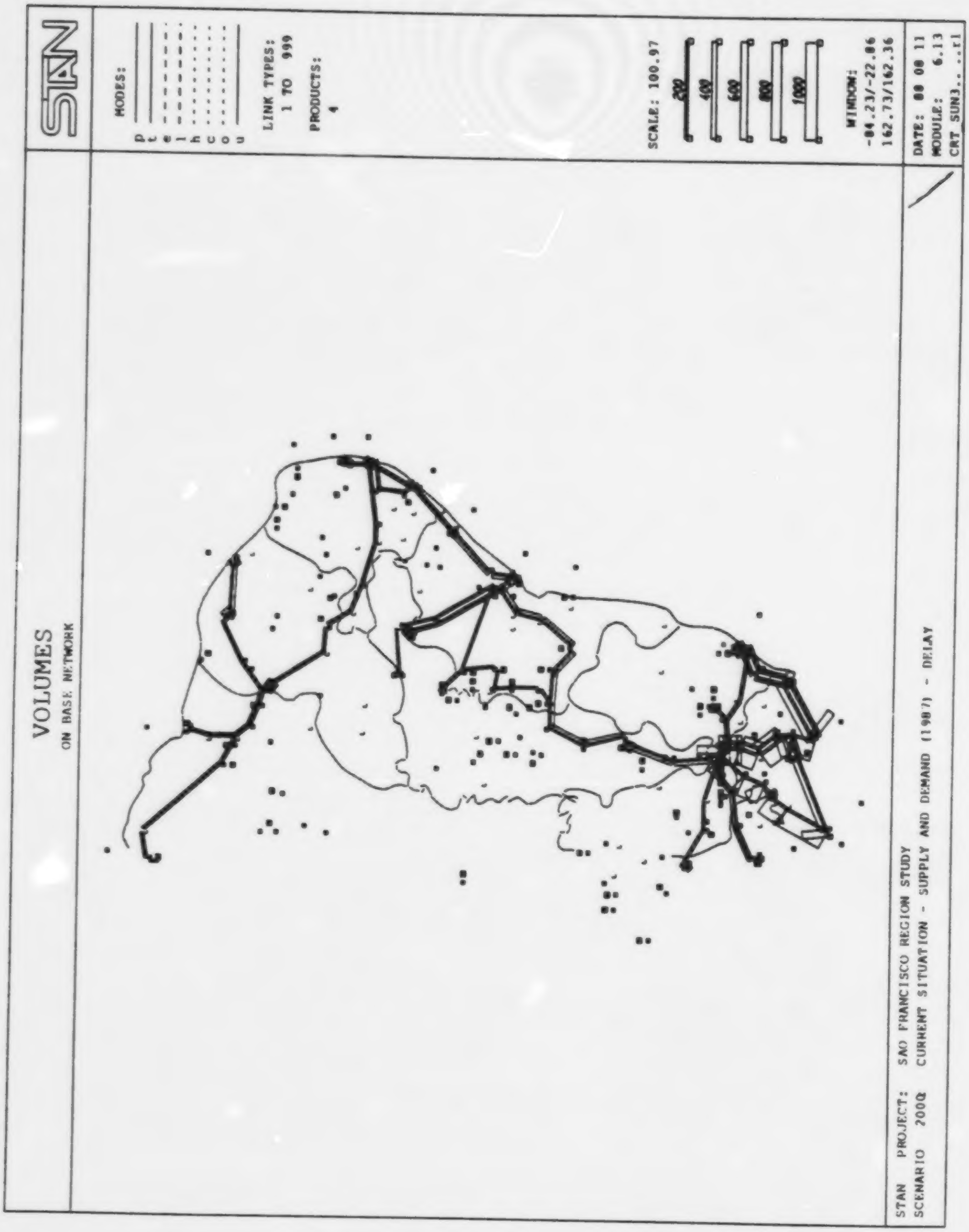
800
1000
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 07
MODULE: 6.13
CRT SUMJ.. ..C9
VOLUMES
ON BASE NETWORK
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 1000 CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST

Figure 39 Cement Transportation - Cost on Current Network


VOLUMES
ON BASE NETWORK
STAN
MODES:
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u
LINK TYPES:
1 TO 999
PRODUCTS:
4
SCALE: 100.97
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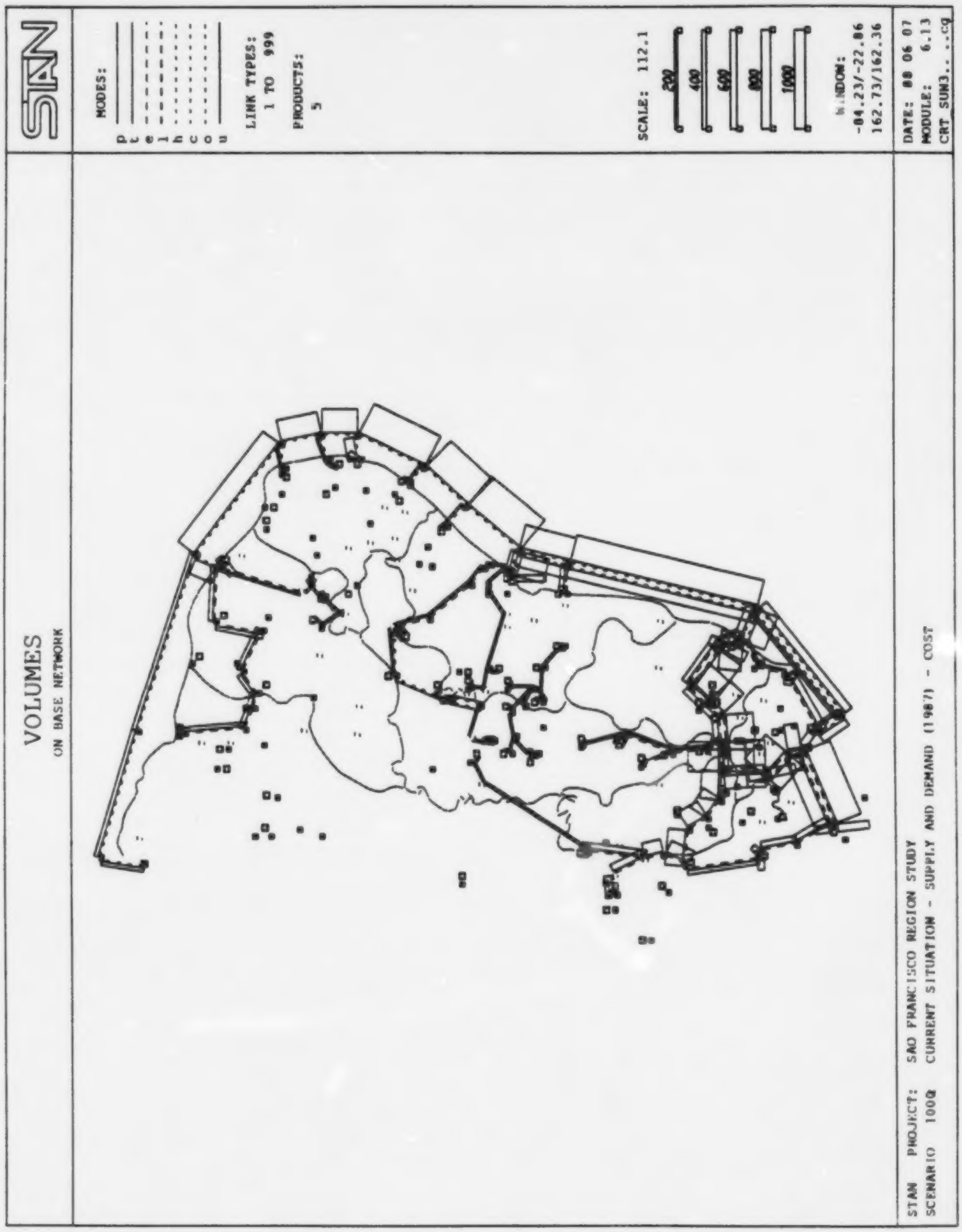
400
600
800
1000
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 08 11
MODULE: 6.13
CRT SUN3... ..rl
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 2000 CURRENT SITUATION - SUPPLY AND DEMAND (1987) - DELAY

Figure 40 Cement Transportation - Delay on Current Network


STAN
VOLUMES
ON BASE NETWORK
MODES:
p
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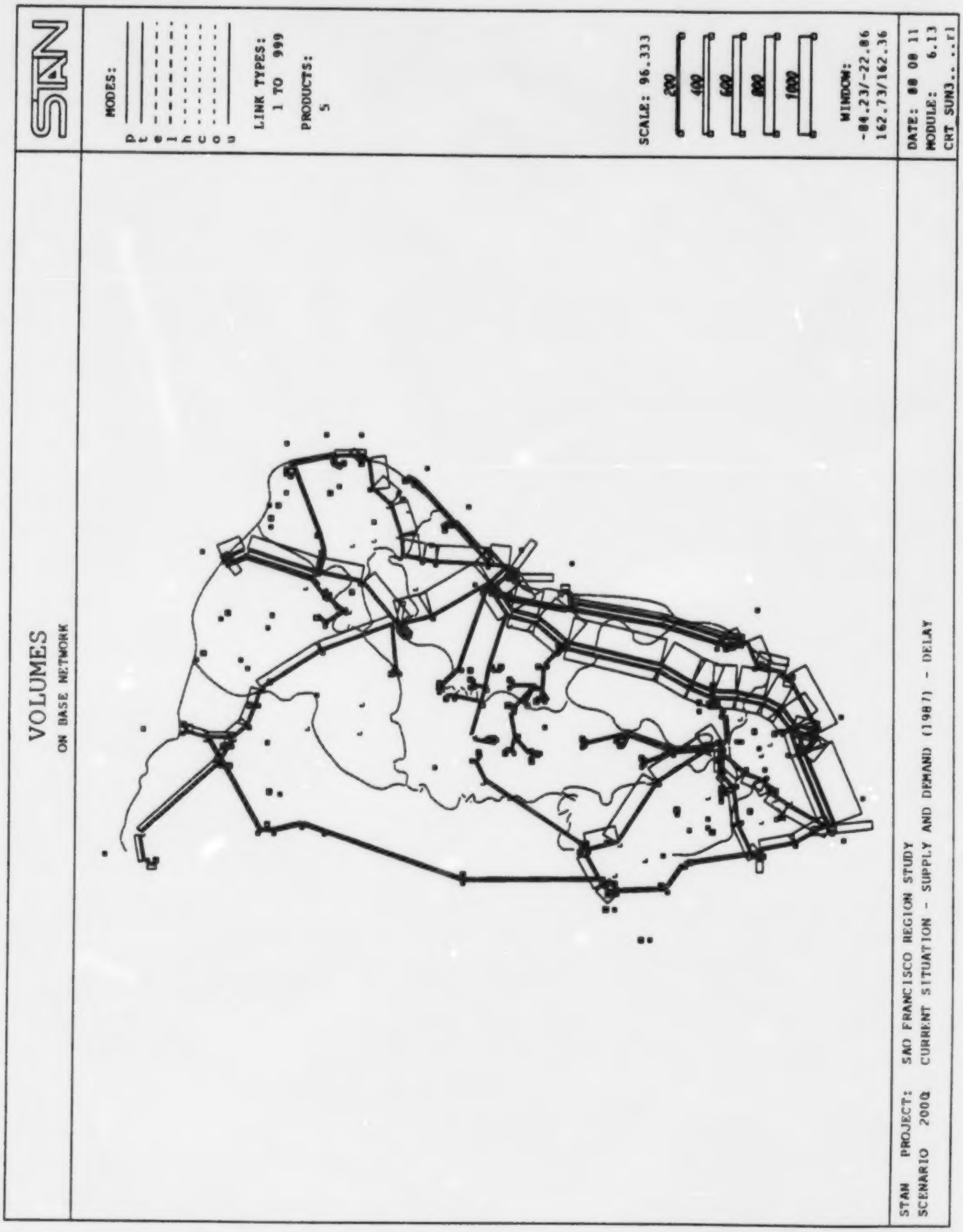
h
c
o
u
LINK TYPES:
1 TO 999
PRODUCTS:
5
SCALE: 112.1
200
400
600
800
1000
WINDOW:
-04.23/-22.86
162.73/162.36
DATE: 88 06 07
MODULE: 6.13
CRT SUN3... ..cg
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100Q CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST

Figure 41 Petroleum Byproducts Transportation - Cost on Current Network


STAN
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c
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LINK TYPES:
1 TO 999
PRODUCTS:
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800
1000
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 08 11
MODULE: 6.13
CRT SUN3... ..rl
VOLUMES
ON BASE NETWORK
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 2000 CURRENT SITUATION - SUPPLY AND DEMAND (1987) - DELAY

Figure 42 Petroleum Byproducts Transportation - Delay on Current Network

To From	p	t	e	l	h	c	Total
p	-	17.4	1249.8	560.0	1.1	-	1828.3
		(17.4)	(1398.2)	(616.2)	(0.2)		(2031.9)
t	19.6	-	-	-	-	-	19.6
							(19.6)
e	166.4	29.4	-	5655.4	42.10	4875.9	10769.1
	(188.4)	(29.3)		(6426.3)	(57.7)	(5827.6)	(12539.3)
l	-	-	2579.7	-	-	-	2579.7
			(3081.4)				(3081.4)
h	1.7	-	12.0	-	-	-	13.7
	(1.7)		(12.0)				(13.7)
c	-	-	2890.3	-	-	8097.9	10988.2
			(3369.5)			(9732.6)	(13102.1)
Total	187.9	46.7	6731.8	6215.4	43.2	12973.8	26189.6
	(219.7)	(46.7)	(7861.2)	(7042.5)	(57.9)	(15560.2)	(30787.9)

Note: The coastal-navigation mode (c) includes port access links.

Table 19 Transfer Volumes - 1987 (1990) Cost on Current Network

To From	p	t	e	l	h	c	Total
p	-	1437.9 (1694.4)	605.5 (649.4)	-	1.1 (0.2)	-	2044.5 (2343.9)
t	1644.7 (1949.9)	-	-	-	-	-	1644.7 (1949.9)
e	399.5 (456.4	-	-	-	-	-	399.5 (456.4)
l	-	-	-	-	-	-	-
h	-	-	-	-	-	-	-
c	-	-	-	-	-	-	-
Total	2044.2 (2406.4)	1437.9 (1694.4)	605.5 (649.4)	-	1.1 (0.2)	-	4088.7 (4750.3)

Table 20 Transfer Volumes - 1987 (1990) Delay on Current Network

the highway mode to the railway in Petrolina is remarkable; it is insignificant, on the other hand, on the waterway-railway transfers in Pirapora and the highway-railway transfers in Ingazeira. In the time based scenario, transfers only occured between the single (u) mode, connecting centroids to the transportation network, and the other modes. In both scenarios, no transshipments were identified in Salgueiro, where the only modal alternatives were the paved and unpaved highway systems.

3.2.3 Analysis of the Sertaneja (Transnortheastern) Railway

With the construction of the Transnortheastern Railway, the utilization of the transportation system was modified by the reduction in railway distances in the Northeast network. The assignment results were different according to the decision criterion used: operating cost or time. The O/D transportation demand for the year 1990 was adopted since the period of construction of the new railway connections was over three years. It is worth pointing out that the flow distribution resulting from an assignment based on the transportation time criterion did not present significant changes when the Transnortheastern railway was added, since the highway is still the most time efficient mode to satisfy the demand within the region.

Table 21 shows aggregate results for the scenarios, for operating costs (Cr$), time (h) and the transportation production (t-km). On the average, operating costs were Cr$ 0.12/t-km and 0.0184 h/t-km. On the other hand, the selection of routes according to the time criterion generated a total amount of tons-km about 30% lower than when cost was the assignment criterion, thus indicating a reduction in the average transportation distance due to the time advantage of the highway mode.

When time was the decision criterion, the modal split polarized transportation on

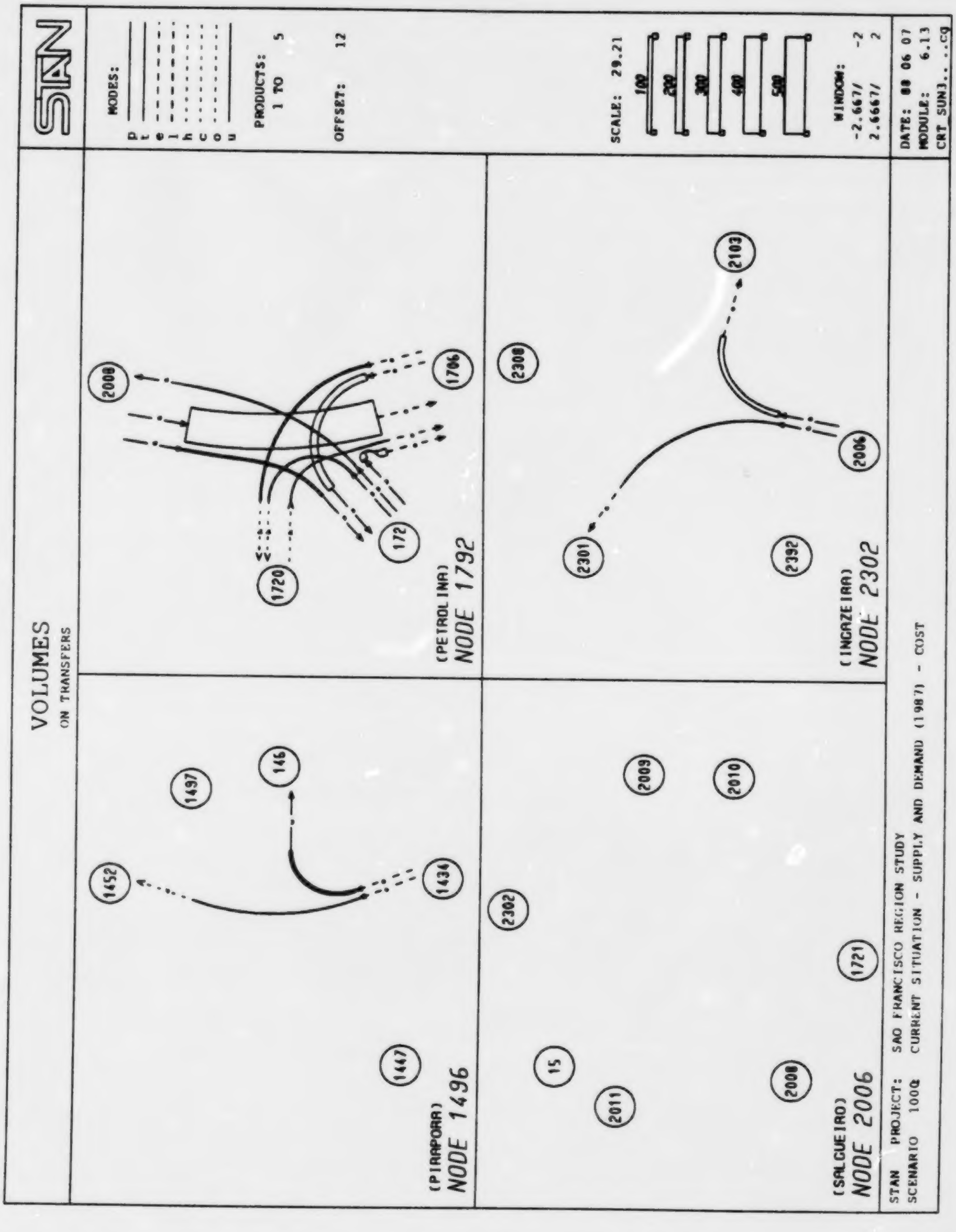

STAN
MODES:
p
t
e
l
h
c
o
u
PRODUCTS:
1 TO 5
OFFSET: 12
SCALE: 29.21
100
200
300
400
500
WINDOW:
-2.667/ -2
2.6667/ 2
DATE: 88 06 07
MODULE: 6.13
CRT SUN3.....cg
VOLUMES
ON TRANSFERS
1452
1497
146
1434
1447
(PIRAPORA)
NODE 1496
2008
1786
172
1720
(PETROLINA)
NODE 1792
2302
2009
2010
1721
15
2011
2008
(SALGUEIRO)
NODE 2006
2308
2103
2006
2301
2392
(INGAZEIRA)
NODE 2302
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100Q CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST

Figure 43 Transfer Flows - Cost on Current Situation

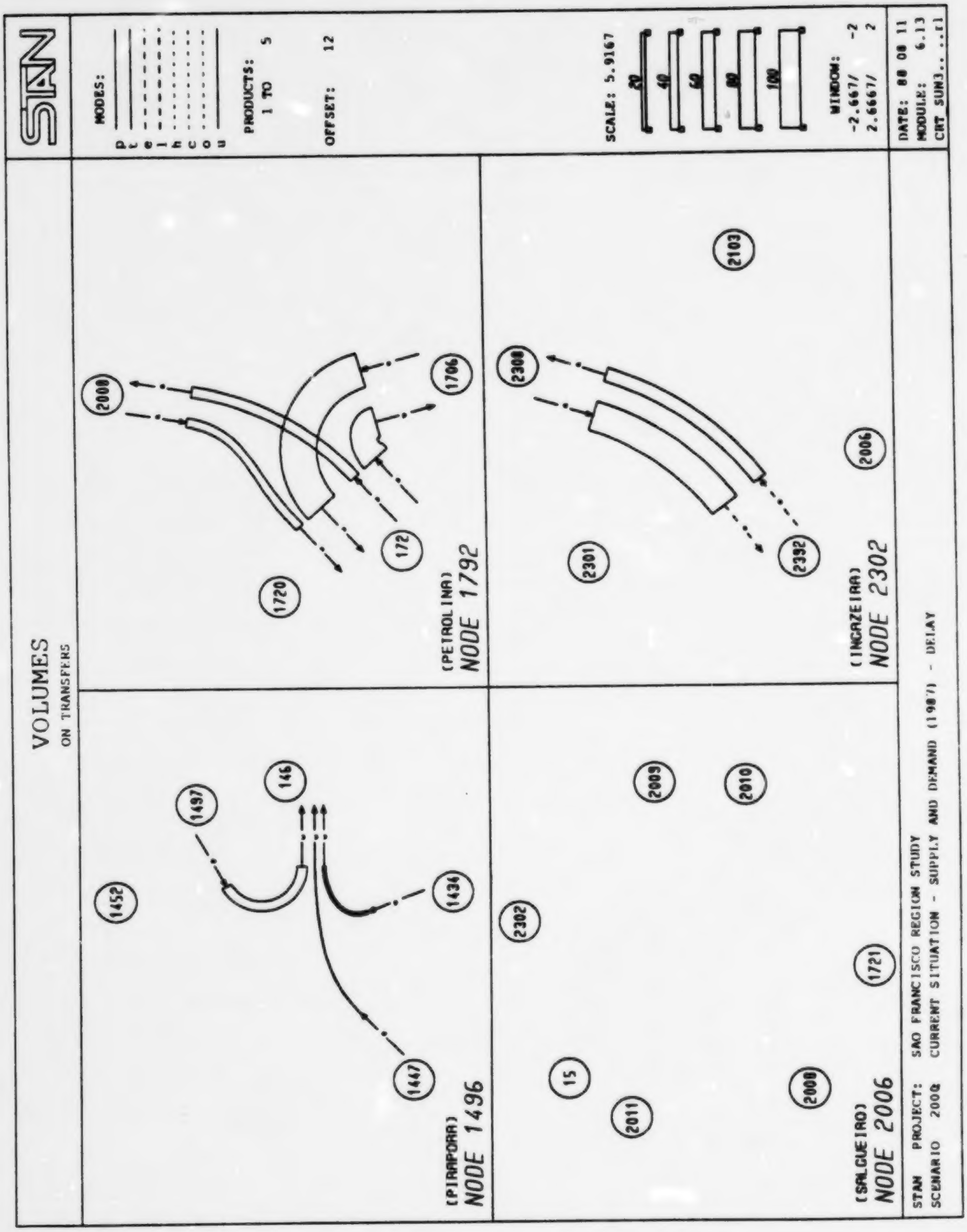

STAN
VOLUMES
ON TRANSFERS
MODES:
p
r
e
l
h
c
o
u
PRODUCTS:
1 TO 5
OFFSET: 12
SCALE: 5.9167
20
40
60
80
100
WINDOW:
-2.667/ -2
2.6667/ 2
DATE: 88 08 11
MODULE: 6.13
CRT SUN3.. ..[1]
(PIRAPORA)
NODE 1496
1452
1497
146
1434
1447
(PETROLINA)
NODE 1792
2000
1706
172
1720
(SALGUEIRO)
NODE 2006
2302
2009
2010
1721
15
2011
2008
(INGAZEIRA)
NODE 2302
2308
2103
2006
2301
2392
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 2000 CURRENT SITUATION - SUPPLY AND DEMAND (1987) - DELAY

Figure 44 Transfer Flows - Delay on Current Situation

Reference Year	Type of Assignment	Objective Value Cr$ or h	Production 10^3 t-km
1990	Cost	0.481666×10^{10}	40517175.2
1987	Time	0.573962×10^{6}	31119787.2

Table 21 Assignment Results - 1990 Scenario

the narrow-gauge railway (see Table 22). When operating cost was used, the use of coastal navigation was also observed. Vehicle fleet estimates were directly and linearly related to the utilization of the transportation modes. In the railway case, a limit of 160 trains/year (adopting an average composition of 40 wagons) was obtained, which is much lower than the capacity of the sections of the transportation network.

The variation intervals for the cost and delay by ton transported in each mode, corresponding to the two assignments, confirm the polarization of the cargo flows (see Figure 45). These intervals take into account the average transportation distance and the products in each system. Here, modal competition, as defined by the superposition of the modal intervals, occurred only between coastal navigation and inland navigation, and only in the operating cost scenario. The final average values for these values also reflect a modal predominance (in terms of t-km): clearly, the highway-railway system for the time scenario, and, less significant, the railway-waterway combination for the cost scenario.

Figures 46 and 47 illustrate the utilization of the transportation system, the total flows assigned to the sections of the transportation network, for the cost and time sce-

Mode	Cost	Time
Paved Road (p)	3860.3 (185)	212208.4 (11424)
Unpaved Road (t)	73.1 (4)	2525.7 (135)
Narrow-gauge Railway (e)	218240.7 (6372)	768.7 (22)
Wide-gauge Railway (l)	18067.6 (499)	-
Inland-navigation Waterway (h)	336.4 (1)	-
Coastal-navigation Waterway (c)		

Table 22 Mode Utilization - 1990 Network

narios, respectively. The selection of routes varied according to the decision criteria, identifying alternative routes in the highway mode itself. Delays and costs at transshipment locations substantially restricted modal integration in the long-distance flows, except for the access to the demand centers.

For scenarios using operating cost as a decision criteria, inter-corridor flows mostly used the railway and coastal navigation modes, especially in the North-South direction. The São Francisco River was used to meet the demand within its area of influence, whereas the highway system only complemented the remaining modes to insure access to freight origin and destination locations. It is noteworthy that the

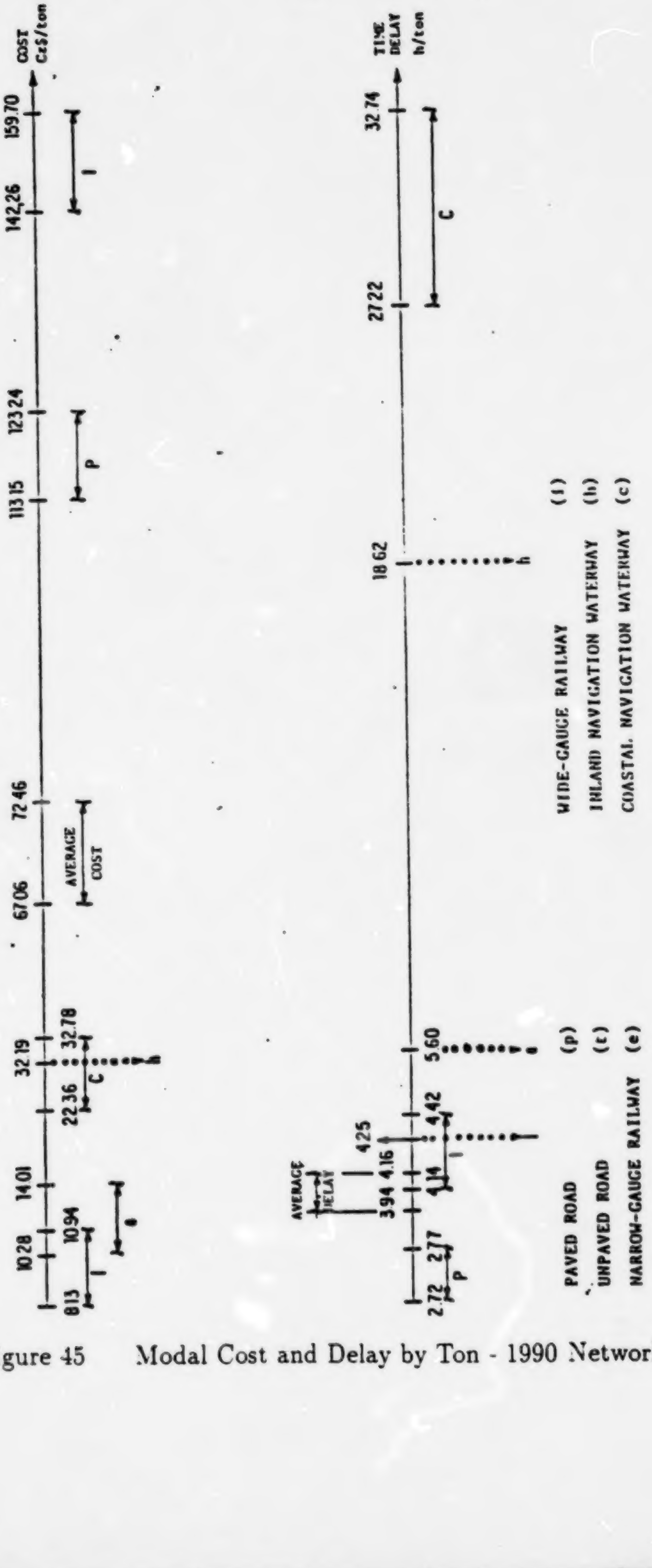
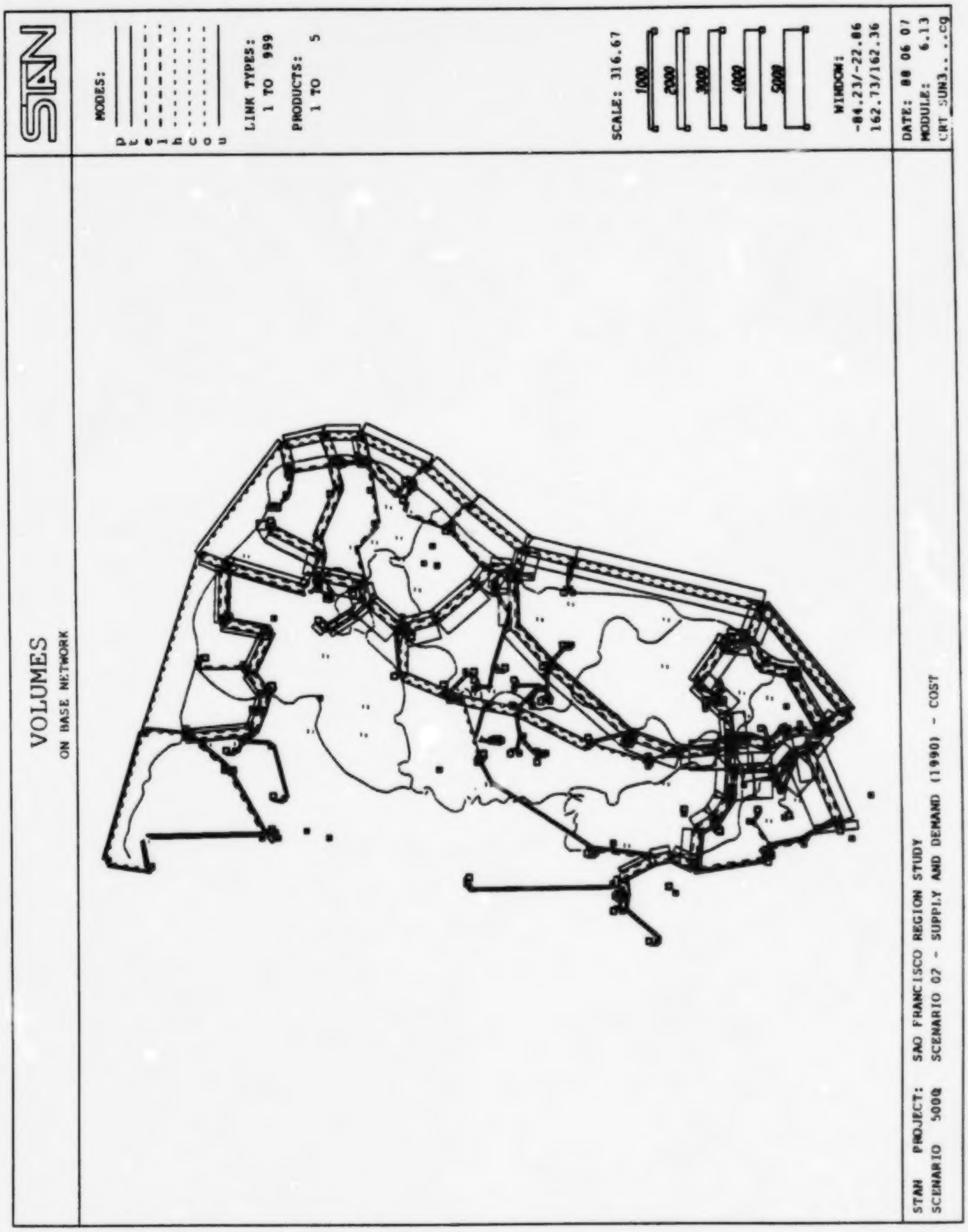


Figure 45 Modal Cost and Delay by Ton - 1990 Network


STAN
VOLUMES
ON BASE NETWORK
MODES:
p
t
e
l
h
c
o
u
LINK TYPES:
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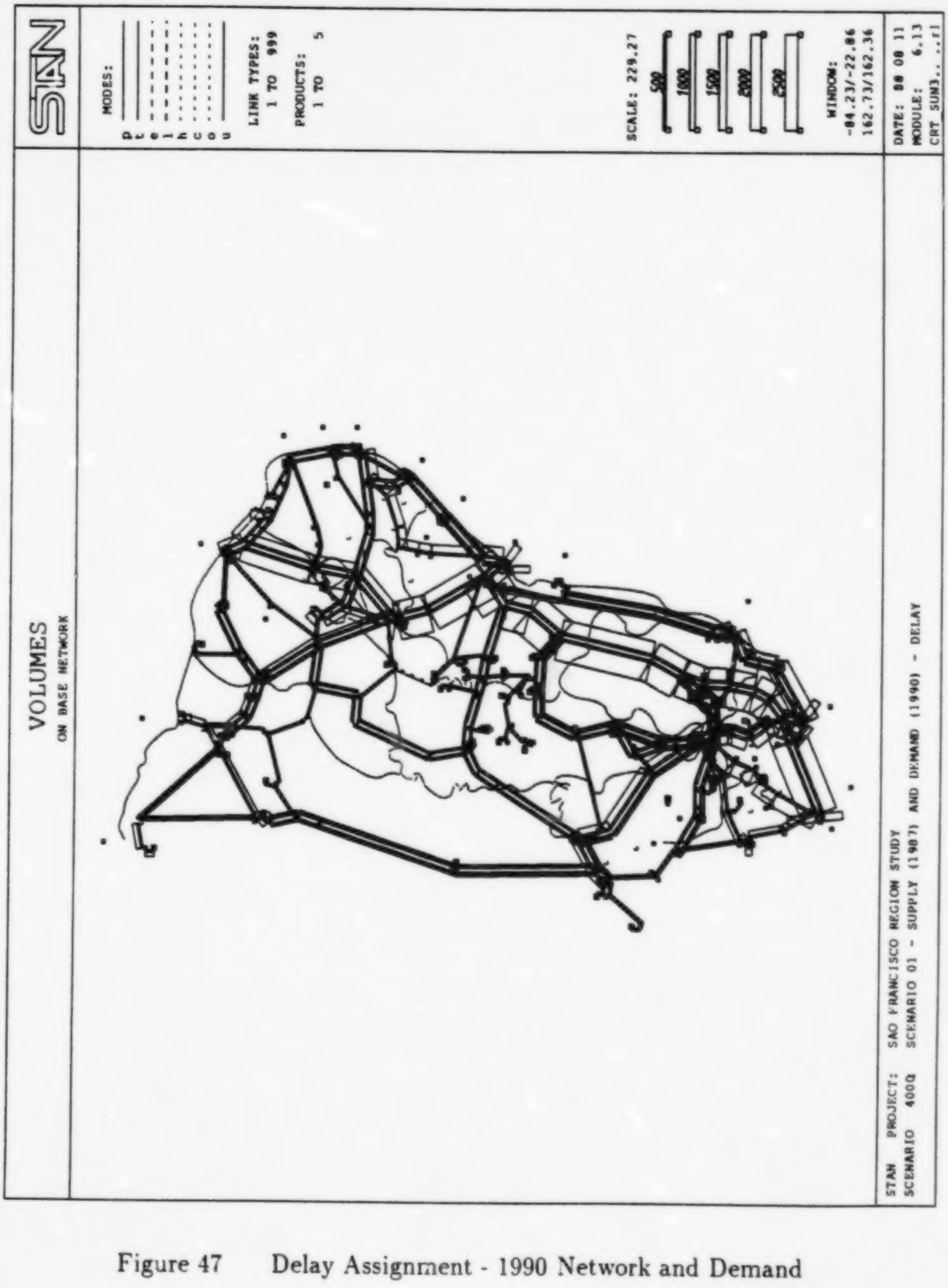
PRODUCTS:
1 TO 5
SCALE: 316.67
1000
2000
3000
4000
5000
WINDOW:
-84.23/-22.86
162.73/162.36
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 500Q SCENARIO 07 - SUPPLY AND DEMAND (1990) - COST
DATE: 88 06 07
MODULE: 6.13
CRT SUN3...cg

Figure 46 Cost Assignment - 1990 Network and Demand


STAN
VOLUMES
ON BASE NETWORK
MODES:
p
t
e
l
h
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o
u
LINK TYPES:
1 TO 999
PRODUCTS:
1 TO 5
SCALE: 229.27
500
1000
1500
2000
2500
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 08 11
MODULE: 6.13
CRT SUN3.. ..rl
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 400Q SCENARIO 01 - SUPPLY (1987) AND DEMAND (1990) - DELAY

Figure 47 Delay Assignment - 1990 Network and Demand

Transnortheastern railway captured an important part of the interior movement on the railway lines in the region, making the region independent from coastal navigation.

For time based scenarios, the utilization of the highway mode was almost exclusive and identified transportation axes between the North-East and Center-South regions. The utilization depended upon the location of the demand and of the transversal feeder roads. No significant railway or waterway flows were predicted, except for a small use of the railway within the Southeast region. In fact, the construction of the Transnortheastern railway did not change the distribution of flows, in relation to the current system, when time is a decision criteria, making it unnecessary to continue the analysis of this scenario.

Here are some observations related to the selected products in the operating cost based scenario:

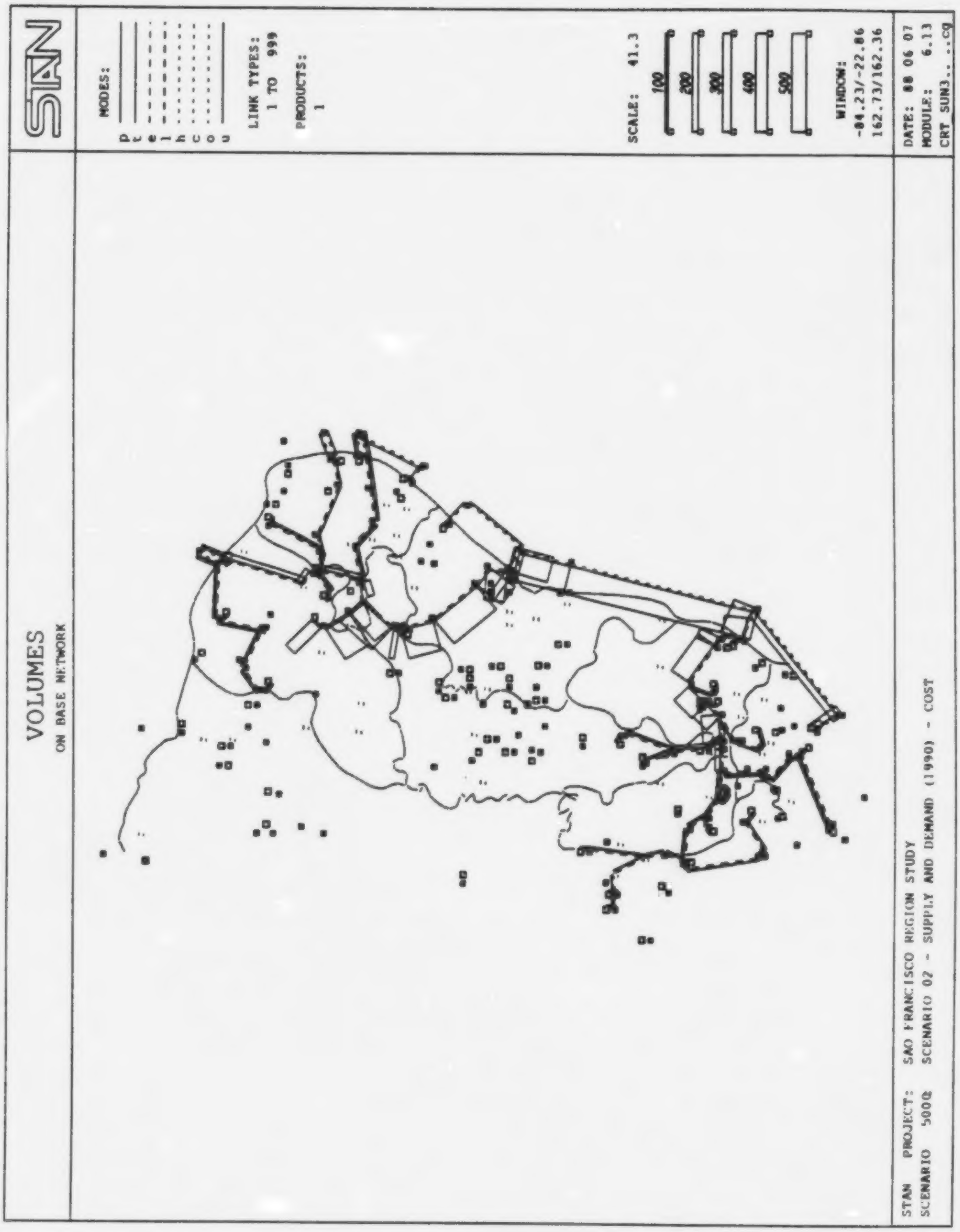
- Transportation of gypsum used the highway-railway system for supplying the North and Center-South regions; coastal navigation was also used for long-distance flows between Salvador and the Southeast ports (see Figure 48);
- Railway was mostly used to transport salt in the interior. The use of the São Francisco waterway and of the coastal navigation was due to the lack of accessibility to the railway and to the shorter transportation distance for the demand located near the coastline, respectively (see Figure 49);
- Solid agricultural bulks used the railway system for long-distance flows, which were fed by roads due to the dispersion of their production. The participation of the São Francisco waterway in the area of direct influence is noted; it is integrated to the railway system at the extremities of the river section at Pirapora and Petrolina/Juazeiro (see Figure 50);
- Cement transportation, most of which is done in the South-North direction,

used predominantly the waterway-railway system with coastal navigation being used only to supply Belém. One also notes that the use of the railways within the Southeast region (see Figure 51);

- The location of production centers near the coastline determined the significant use of coastal navigation in the transportation of petroleum byproducts, the interior distribution being insured by the railway system. The railway replaced the waterway in supply centers north of Fortaleza, mainly because the travel distance is short through the interior following the construction of the Transnortheastern railway. Alcohol flows were also noted in the area of influence of the corridor (see Figure 52).

In general, the Transnortheastern railway contributed to the movement of all products, with the exception of cement, and allowed the flows to penetrate the interior from Salvador. The connections with the São Francisco waterway system was principally used for the transportation of agricultural bulk products.

Important inter-modal transfers (from 25% to 40%) may be observed (see Table 23) between the narrow-gauge railway and the wide-gauge subsystem and coastal navigation. A total 75 thousand tons/year were observed moving through the ports on the São Francisco river, which was much below their capacities. Figure 53 illustrates the utilization of transshipment at the following locations: Pirapora (1496), Petrolina (1972), Salgueiro (2006) and Ingazeira (2302). At these nodes, one notes the predominance of transshipments involving the single (u) mode (responsible for the connection of the centroids to the transportation network) in addition to some waterway-railway movement of little significance. In fact, these estimates indicate that the Transnortheastern railway also played a role in determining uni-modal transportation for the long-distance traffic, determined, among other factors, by the high cost of transshipment operations and by the topology of the modal networks.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e
l
h
c
o
u
LINK TYPES:
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PRODUCTS:
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200
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400
500
WINDOW:
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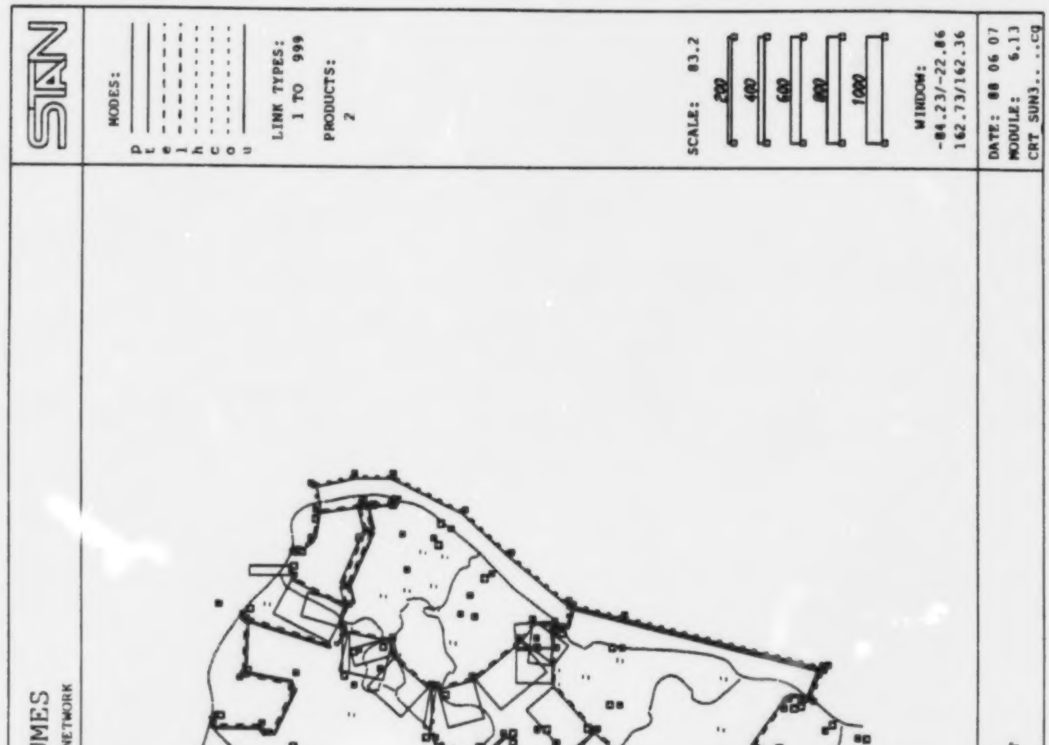
162.73/162.36
DATE: 88 06 07
MODULE: 6.13
CRT SUN3.. ..cg
VOLUMES
ON BASE NETWORK
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 5002 SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST

Figure 48 Gypsum Transportation - 1990 Scenario


VOLUMES
ON BASE NETWORK
STAN
MODES:
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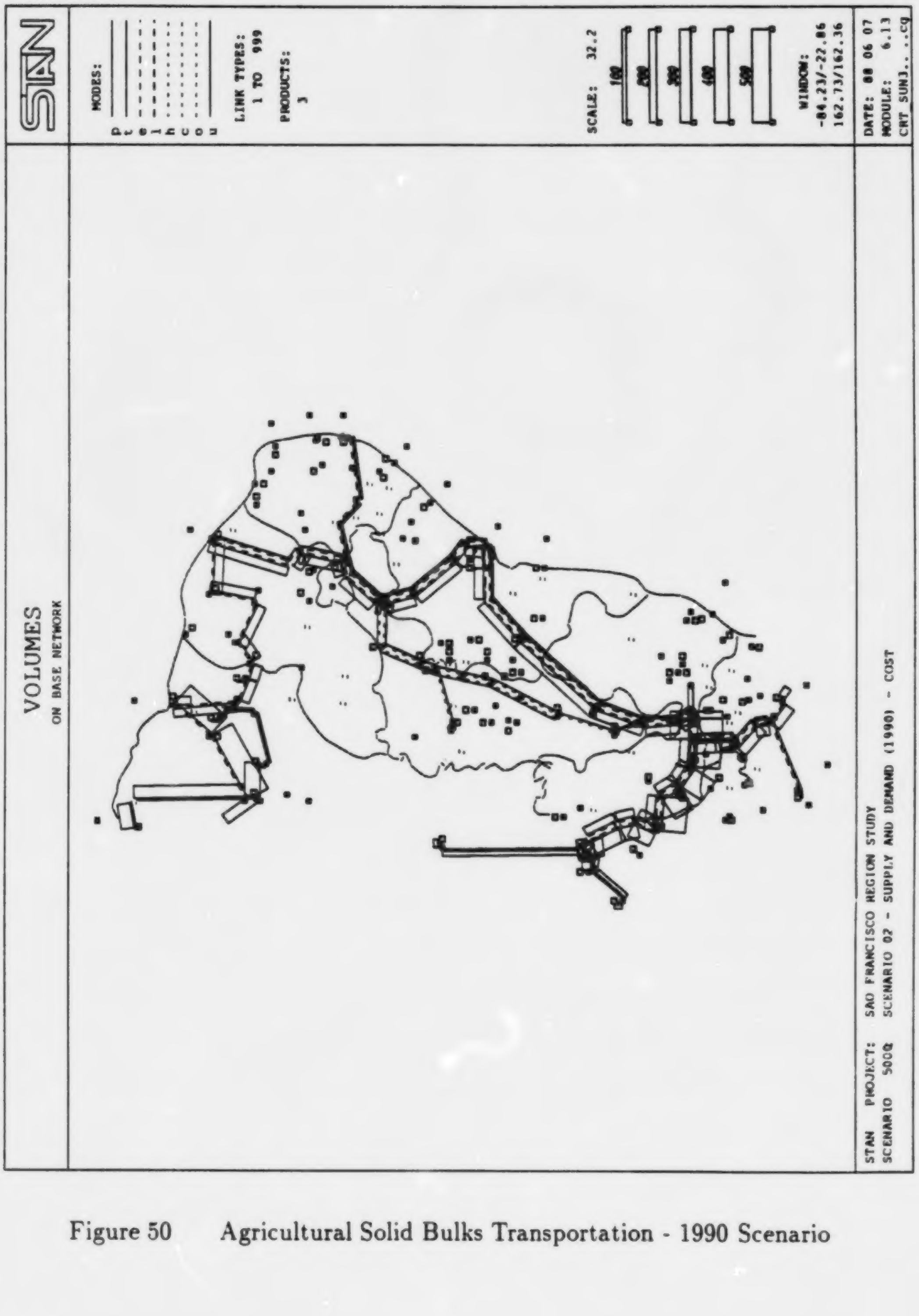
e
l
h
c
o
u
LINK TYPES:
1 TO 999
PRODUCTS:
2
SCALE: 83.2
200
400
600
800
1000
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 07
MODULE: 6.13
CRT SUN3... ..cg
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 500Q SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST

Figure 49 Salt Transportation - 1990 Scenario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MODES:
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c
o
u
LINK TYPES:
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PRODUCTS:
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SCALE: 32.2
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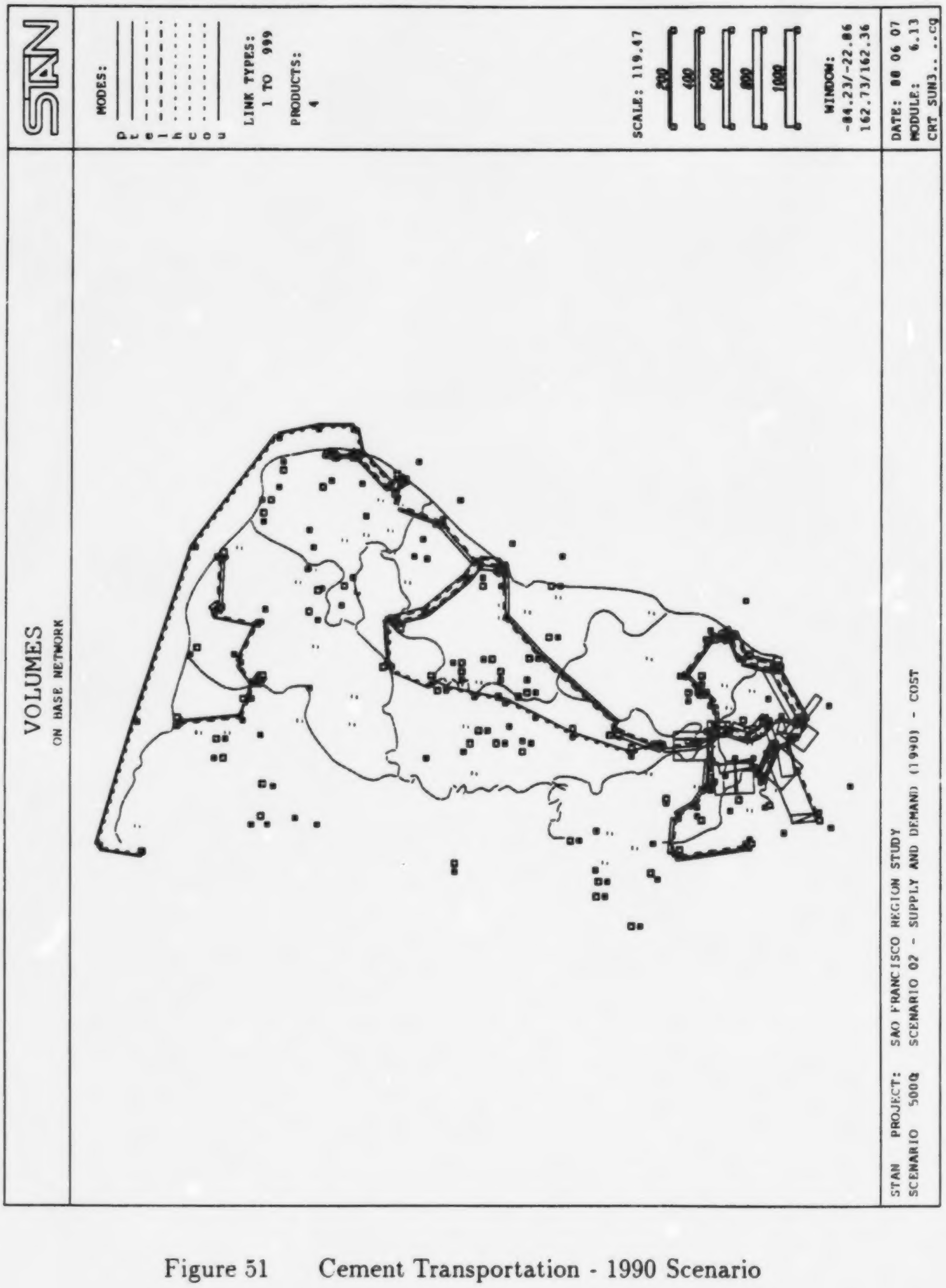
400
500
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 07
MODULE: 6.13
CRT SUN3.. ..cg
VOLUMES
ON BASE NETWORK
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 500Q SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST

Figure 50 Agricultural Solid Bulks Transportation - 1990 Scenario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ON BASE NETWORK
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PRODUCTS:
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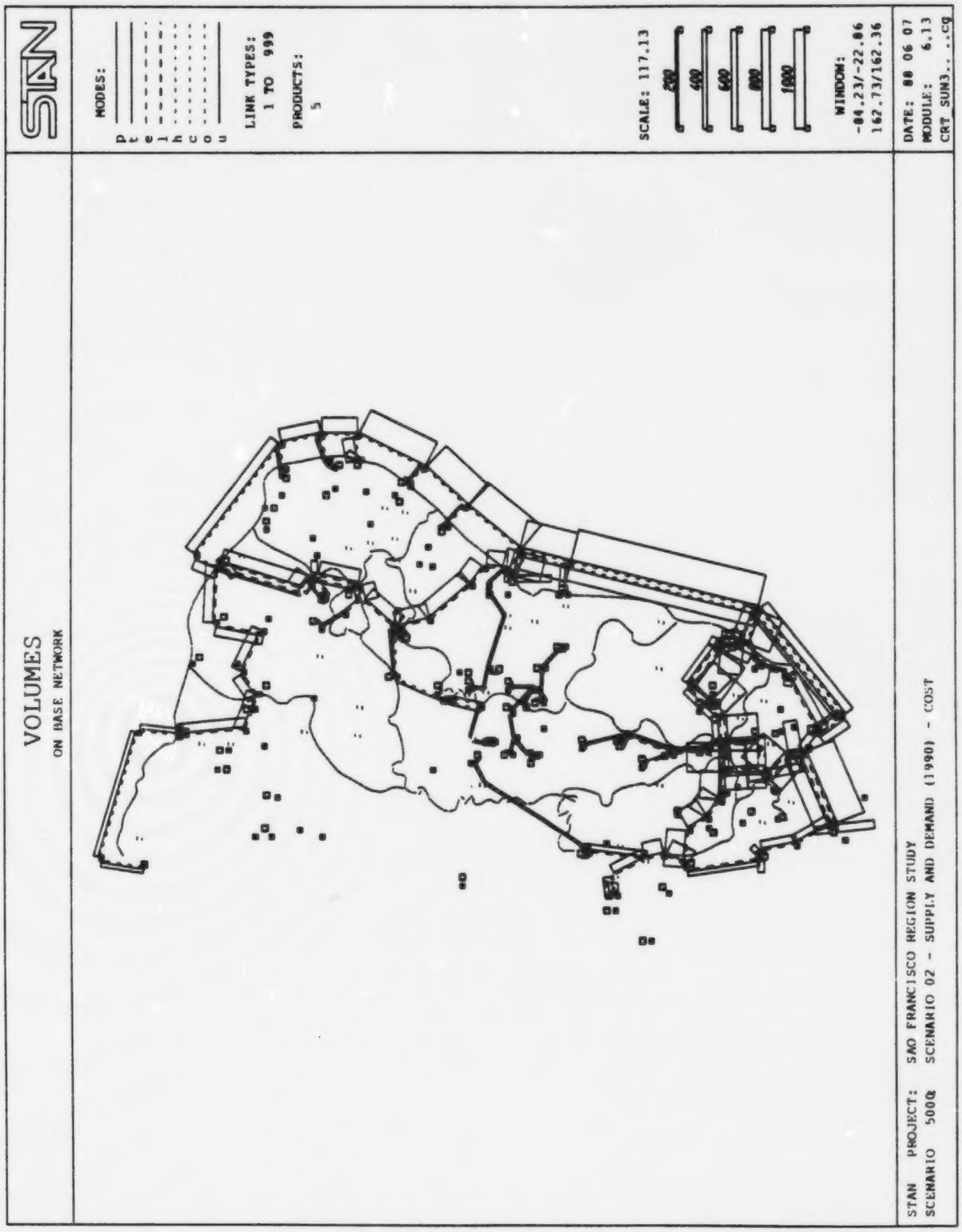
600
800
1000
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 07
MODULE: 6.13
CRT SUN3.. ..cg
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 500Q SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST

Figure 51 Cement Transportation - 1990 Scenario


STAN
VOLUMES
ON BASE NETWORK
MODES:
p
t
e
l
h
c
o
u
LINK TYPES:
1 TO 999
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200
400
600
800
1000
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 07
MODULE: 6.13
CRT SUN3.. ..cg
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 500Q SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST

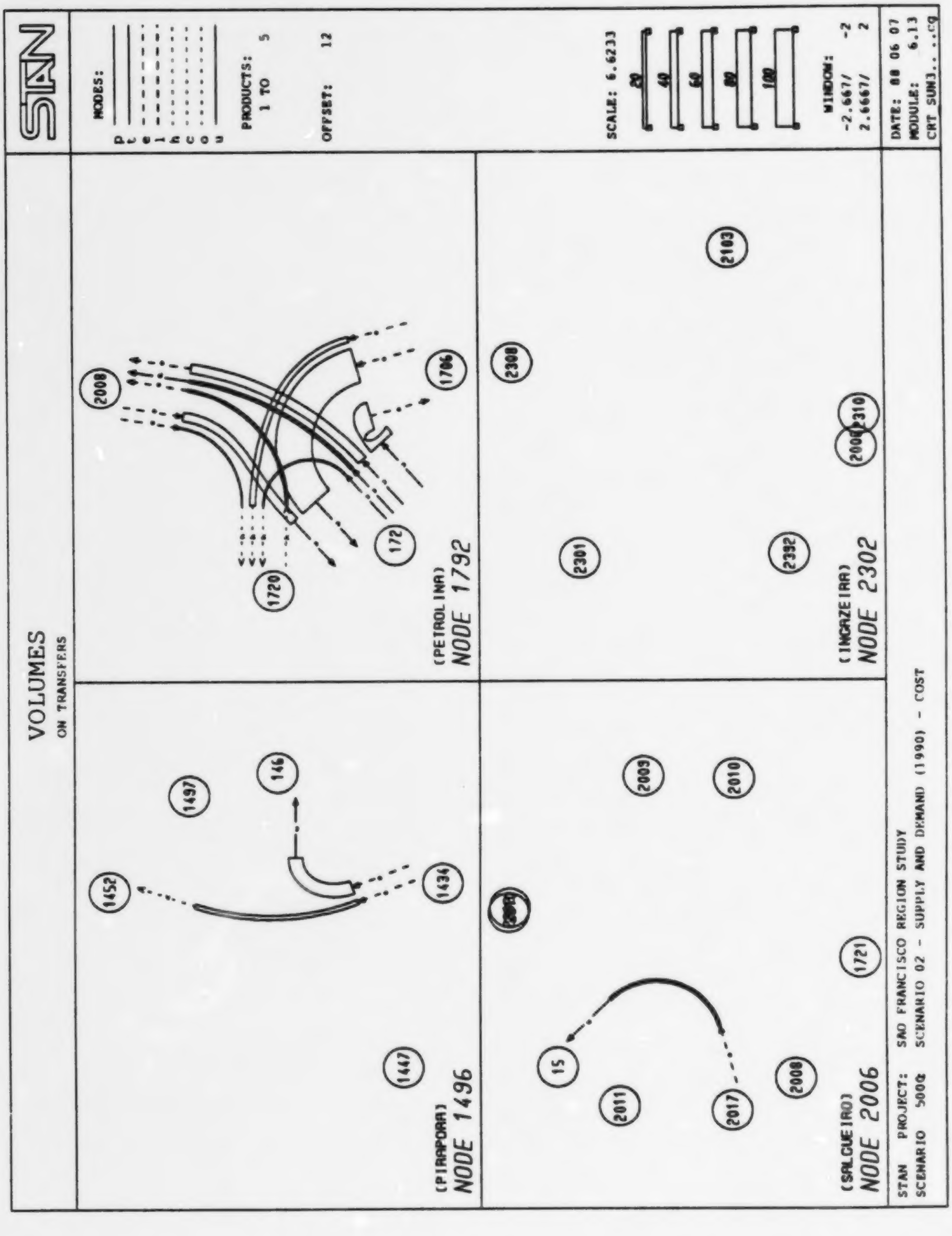
Figure 52 Petroleum Byproducts - 1990 Scenario

	p	t	e	l	h	c	Total
p	-	17.4	1510.4	616.22	-	-	2143.9
t	19.6	-	-	-	-	-	19.6
e	206.7	29.2	-	7006.5	74.6	4003.9	11320.9
l	-	-	3081.5	-	-	-	3081.5
h	7.2	-	12.0	-	-	-	19.2
c	-	-	1588.5	-	-	6959.3	8547.8
Total	233.5	46.6	6192.3	7622.7	74.6	10963.2	25132.9

Table 23 Transfer Volumes - 1990 Scenario

3.2.4 Comparison of Scenarios

When comparing the resulting flows in the different scenarios, differences in the utilization of the transportation system were noted both due to the evolution of demand between 1987 and 1990 and to the construction of the Transnortheastern railway. The two assignment criteria were considered when analysing the differences. Among the immediate consequences of these comparisons, there are the economic evaluations of investments in the transportation sector, by methods such as the cost/benefit analyses and the calculation of the internal rate of return. These evaluations are performed outside the STAN system.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VOLUMES
ON TRANSFERS
MODES:
p
r
e
l
h
c
o
u
PRODUCTS:
1 TO 5
OFFSET: 12
SCALE: 6.6233
20
40
60
80
100
WINDOW:
-2.667/ -2
2.6667/ 2
DATE: 88 06 07
MODULE: 6.13
CRT SUN3.. ..C9
(PIRAPORA)
NODE 1496
1452
1497
146
1434
1447
(PETROLINA)
NODE 1792
2008
1706
172
1720
(SALGUEIRO)
NODE 2006
2009
2010
1721
15
2011
2017
2008
(INGAZEIRA)
NODE 2302
2308
2103
2310
2008
2301
2392
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 500G SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST

Figure 53 Transfers Flows - 1990 Scenario

Table 24 compares the total costs and delays between the scenarios. For the demand evolution (Table 24a with the current transportation network), a total increase of Cr\$ 0.72343 x 10^9 and of 0.086309 x 10^6 hours was predicted, which corresponds to an average growth of 16%, which is proportioned to the increase of the transportation demand. The construction of the Transnortheastern railway (Table 24b with the 1990 demand), generated a saving of Cr\$ 0.50912 x 10^9, which corresponds to about 10% of the total transportation cost in 1990 without the new railway line. The 65 hours difference observed in the time scenarios is only a result of the precision of the iterative nature of the assignment algorithm. The demand evolution did not imply a different utilization of the transportation system but only an increase in the volumes assigned to the routes. On the other hand, the construction of the Transnortheastern railway led to a more economic redistribution of the flows, at least when operating cost was the decision criterion. It is worth noting that the constant value of the total impedance, in the time scenario, reflects an almost exclusive use of the highway mode to meet the transportation demand.

As to modal split, Table 25 shows the comparison of volumes transported by each mode in the various scenarios. The evolution of demand did not generate differences in the modal utilization of the transportation system, except the proportional increase of the new volumes on the same routes. The construction of the Transnortheastern railway resulted, however, in a larger freight captivation by the rail mode, reducing principally the use of coastal navigation when operating cost was considered (the modal split was unchanged when time was the assignment criterion). This redistribution of flows also reduced the total tons-km travelled by shortening the railway distances in the North-East. The São Francisco waterway also had a substantially increased the volume of freight due to the construction of the Transnortheastern railway.

Demand		
	1987	1990
Cost (Cr$)	0.460235 x 10^{10}	0.532578 x 10^{10}
Time (h)	0.487589 x 10^{6}	0.573897 x 10^{6}

Table 24a Demand Scenario

Supply		
	Current	With Transnortheastern Railway
Cost (Cr$)	0.532578 x 10^{10}	0.481666 x 10^{10}
Time (h)	0.573897 x 10^{6}	0.573962 x 10^{6}

Table 24b Network Scenario

Table 24 Total Cost and Delay Comparison

Mode		Demand 1990 - 1987		Supply (Current - New Rail Line)	
		Cost	Time	Cost	Time
Paved Road	(p)	529.6 (26)	30439.0 (1642)	-2465.8 (-125)	19.4 (1)
Unpaved Road	(t)	1.9 (-)	376.4 (20)	-0.4 (-)	- (-)
Narrow-gauge Railway	(e)	23184.1 (681)	60.9 (2)	46184.1 (1298)	- (-)
Wide-gauge Railway	(l)	2504.9 (69)	-	580.2 (14)	- (-)
Inland-navigation Waterway	(h)	48.8 (-)	23.4 (-)	74.7 (-)	24.5 (-)
Coastal-navigation Waterway	(c)	7731.6 (1)	-	-22684.8 (-4)	- (-)
10^3 t-km Total		6,010,725.9	1,668,914.9	-705065.1	2398.6
Transfered Volume (10^3 t)		4,598.3	661.6	-5665.0	1.7

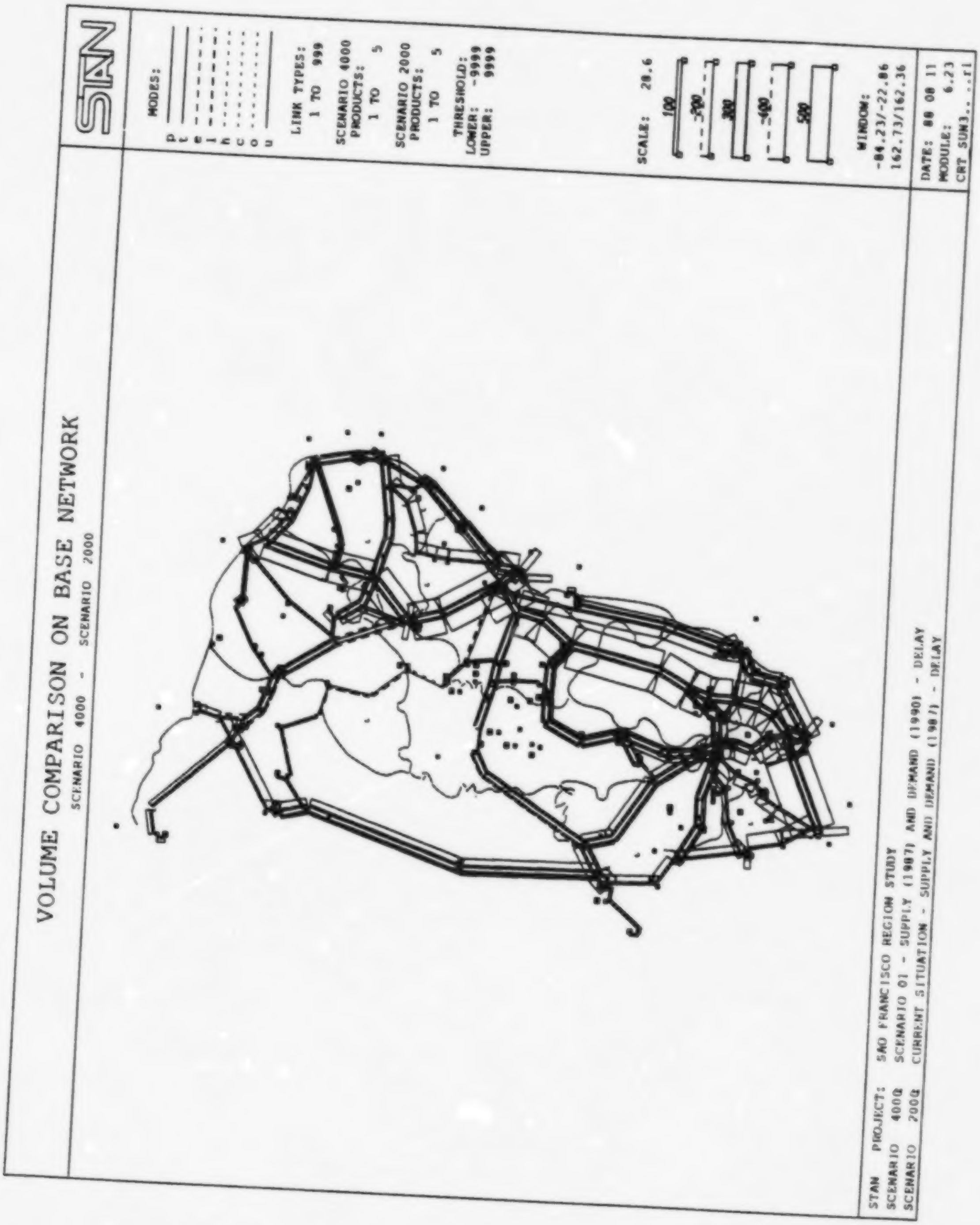
Table 25 Mode Utilization - Comparisons

Modal integration, as observed by the transshipment volumes, displayed a positive growth with the evolution of demand and a negative one with the construction of the Transnortheastern railway. If, for the former, the utilization of the same transportation routes with an increased demand was confirmed, for the latter the exclusive use of the railway for the long-distance traffic increased. This fact implies a new role for a mode that before was considered a mere complement to coastal navigation, for transporting freight to the interior of the region.

The utilization of the transportation system was also analyzed by the superposition of plots illustrating the distribution of the freight flows. For the time scenario, Figures 54 and 55 show a proportional volume increase due to the evolution of demand, and a non-significant redistribution of flows due to the construction of the Transnortheastern railway.

The results are similar when operating costs are the assignment criteria and the evolution of demand is examined (see Figure 56): a proportional increase of utilization of the same transportation routes. Following the construction of the Transnortheastern railway, Figure 57 shows negative flow differentials for coastal navigation, mainly in the Northeast, and a proportional increase in the alternative railway system. The railway lines perpendicular to the coastline have reduced volumes for the interior-bound direction, and somewhat increased in the direction of the centers near the coastline. The São Francisco river also increased its transported volume, as a result of its integration with the railway system in Pirapora and Petrolina, although it still attracts principally flows within its area of direct influence. Therefore, the Transnortheastern railway constitutes an important railway investment that increases the captivation of the long distance freight flows by this mode in Northeast region.

Here are some observations concerning the comparison of the flow distribution for


VOLUME COMPARISON ON BASE NETWORK
SCENARIO 4000 - SCENARIO 2000
STAN
MODES:
p
t
e
l
h
c
o
u
LINK TYPES:
1 TO 999
SCENARIO 4000
PRODUCTS:
1 TO 5
SCENARIO 2000
PRODUCTS:
1 TO 5
THRESHOLD:
LOWER: -9999
UPPER: 9999
SCALE: 28.6
100
-500
300
-400
500
WINDOW:
-84.23/-22.86
162.73/162.36
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MODULE: 6.23
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SCENARIO 4000 SCENARIO 01 - SUPPLY (1987) AND DEMAND (1990) - DELAY
SCENARIO 2000 CURRENT SITUATION - SUPPLY AND DEMAND (1987) - DELAY

Figure 54 Scenario Comparison - Demand/Time

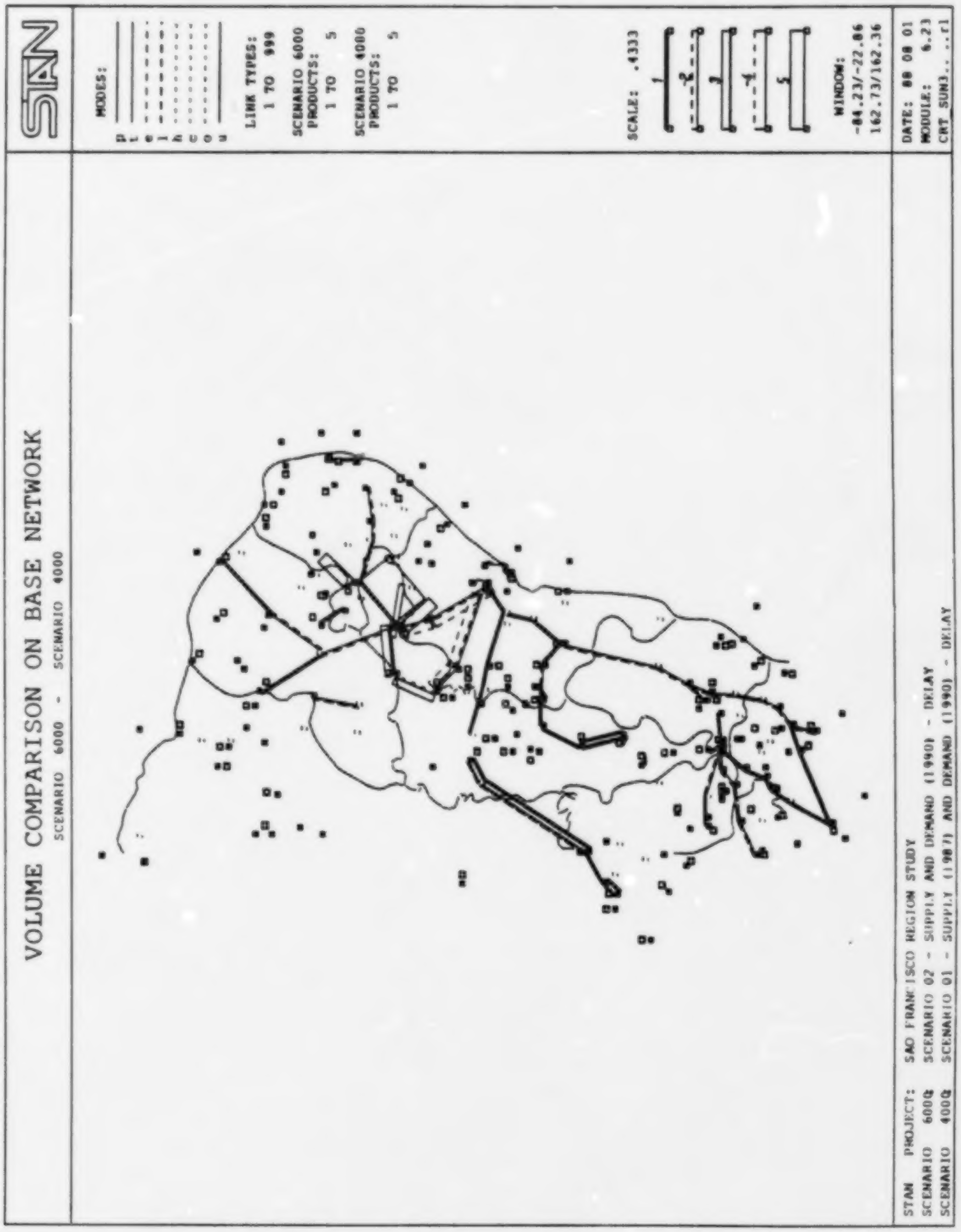
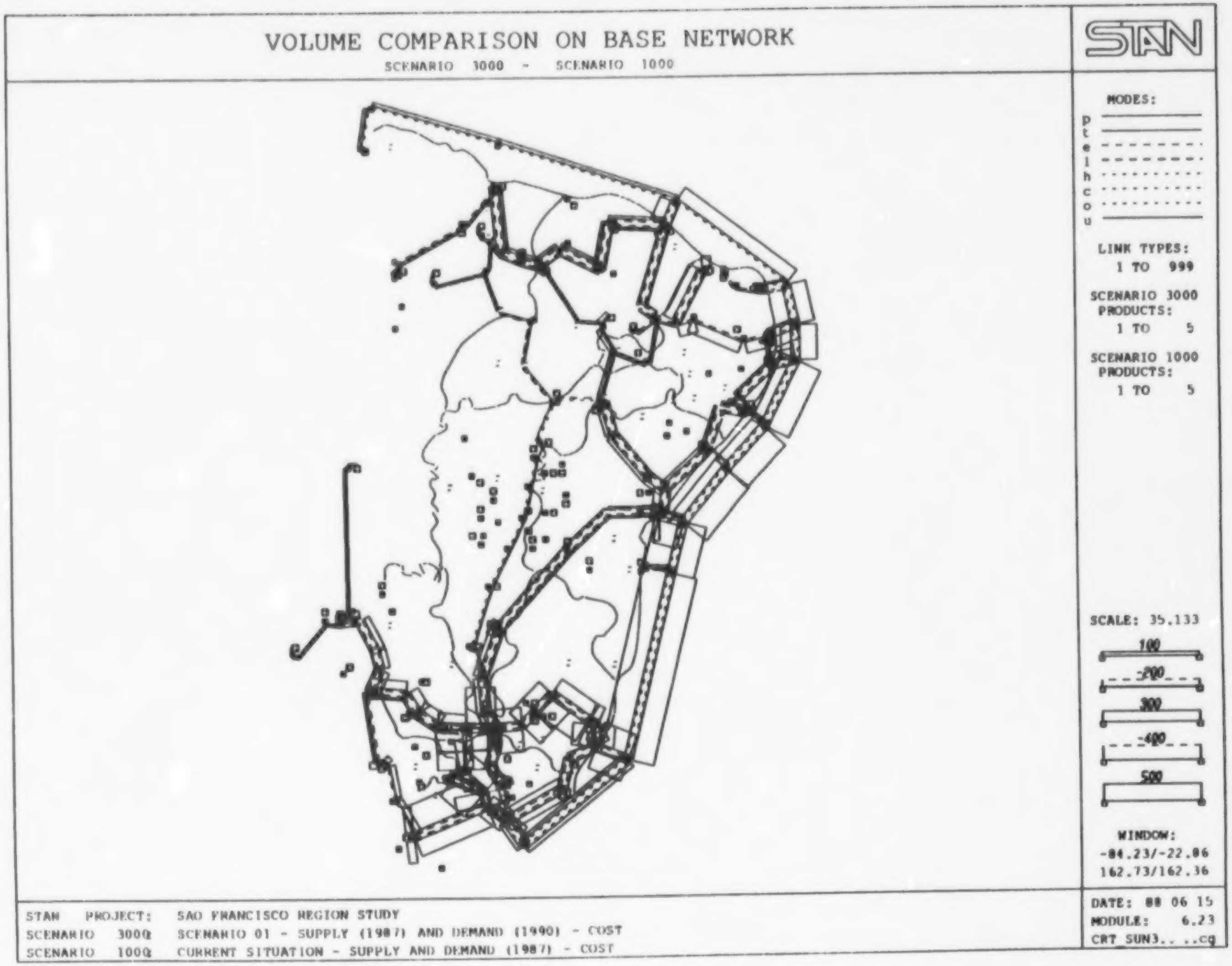

VOLUME COMPARISON ON BASE NETWORK
SCENARIO 6000 - SCENARIO 4000
STAN
MODES:
LINK TYPES:
1 TO 999
SCENARIO 6000
PRODUCTS:
1 TO 5
SCENARIO 4000
PRODUCTS:
1 TO 5
SCALE: .4333
1
2
3
4
5
WINDOW:
-84.23/-22.86
162.73/162.36
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 6000 SCENARIO 02 - SUPPLY AND DEMAND (1990) - DELAY
SCENARIO 4000 SCENARIO 01 - SUPPLY (1987) AND DEMAND (1990) - DELAY
DATE: 88 08 01
MODULE: 6.23
CRT SUN3.. ..rl

Figure 55 Scenario Comparison - Network/Time


VOLUME COMPARISON ON BASE NETWORK
SCENARIO 3000 - SCENARIO 1000
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MODES:
p
t
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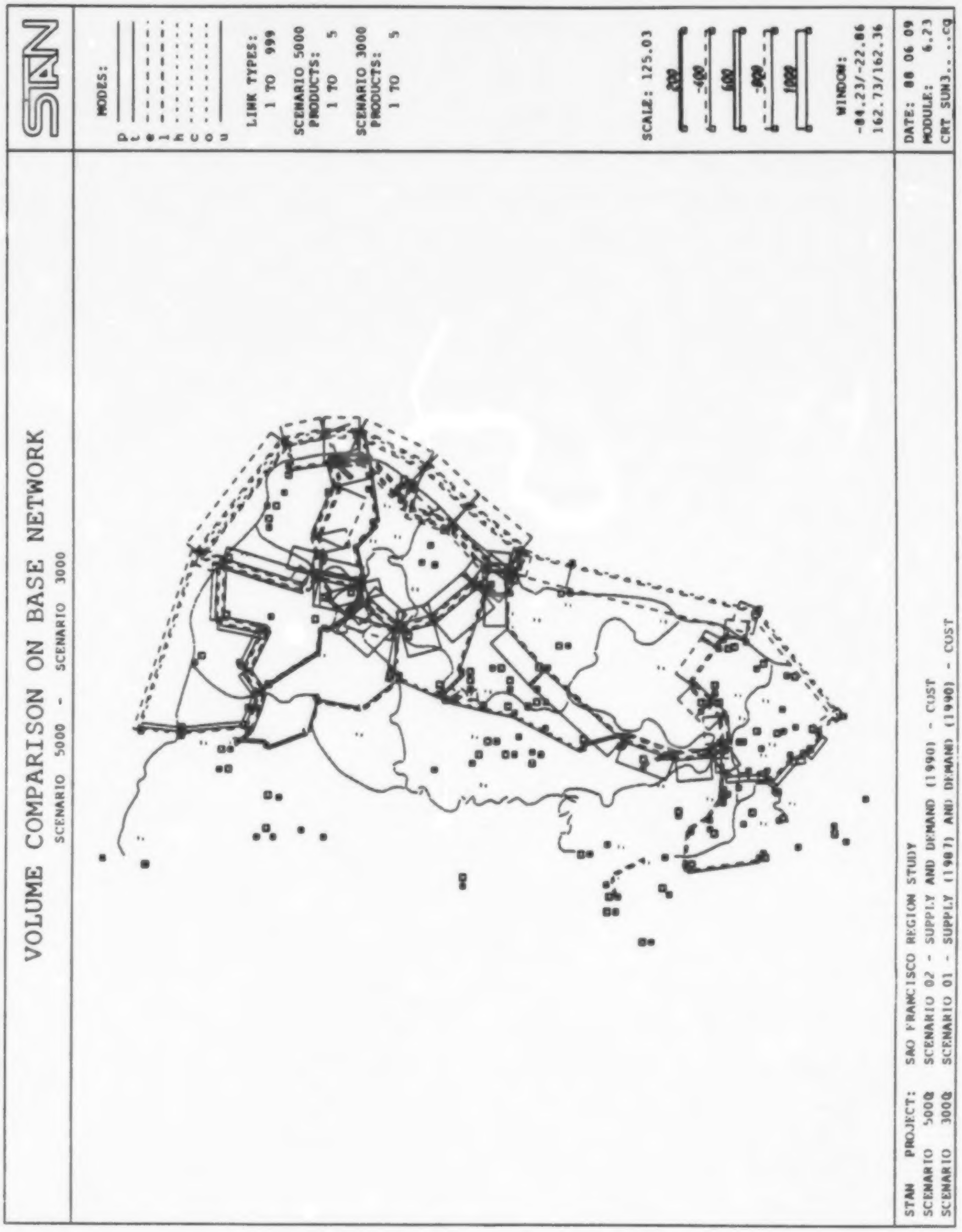
l
h
c
o
u
LINK TYPES:
1 TO 999
SCENARIO 3000
PRODUCTS:
1 TO 5
SCENARIO 1000
PRODUCTS:
1 TO 5
SCALE: 35.133
100
-200
300
-400
500
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 15
MODULE: 6.23
CRT SUN3.. ..cq
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 3000 SCENARIO 01 - SUPPLY (1987) AND DEMAND (1990) - COST
SCENARIO 1000 CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST

Figure 56 Scenario Comparison - Demand/Cost


VOLUME COMPARISON ON BASE NETWORK
SCENARIO 5000 - SCENARIO 3000
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MODES:
p
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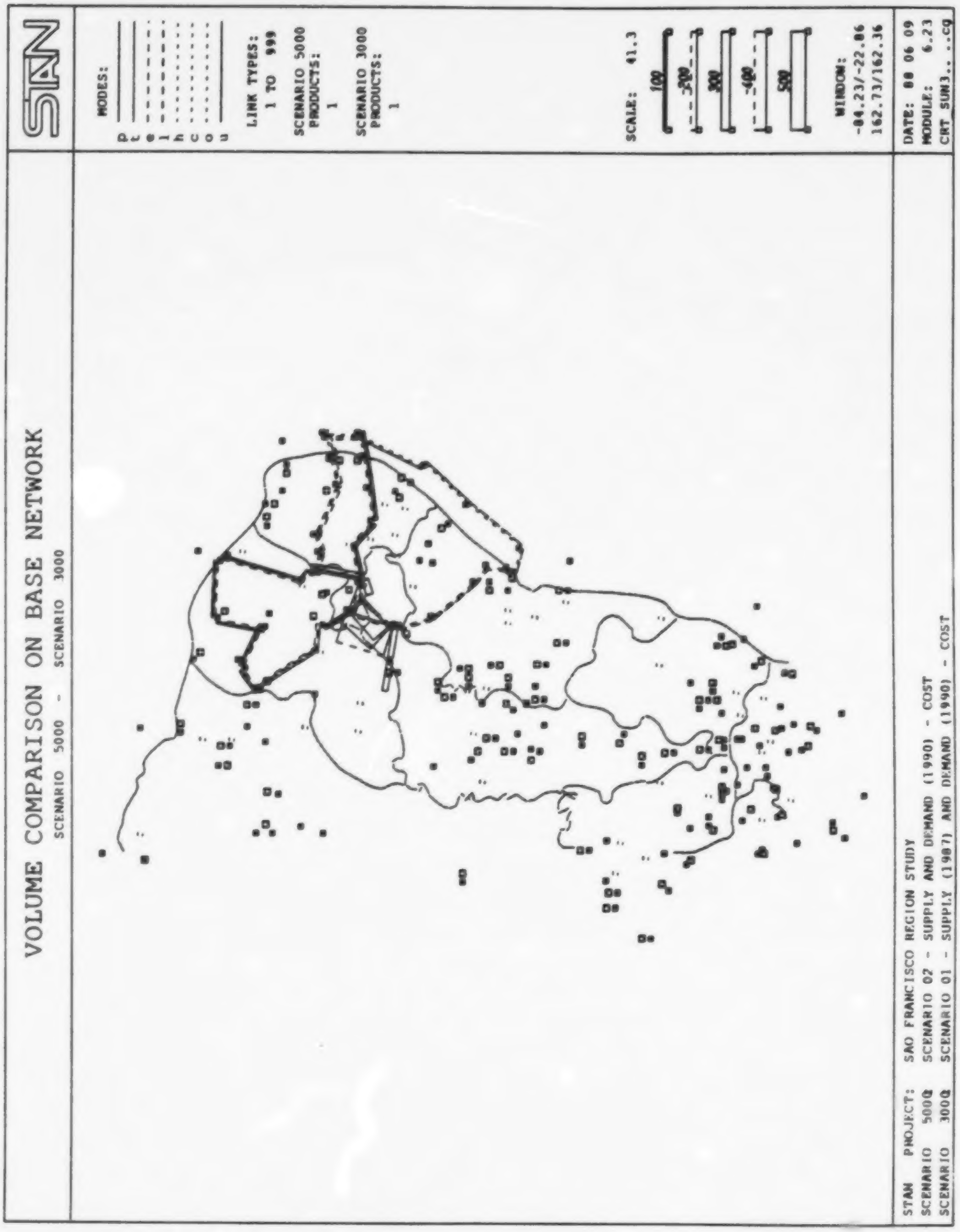
h
c
o
u
LINK TYPES:
1 TO 999
SCENARIO 5000
PRODUCTS:
1 TO 5
SCENARIO 3000
PRODUCTS:
1 TO 5
SCALE: 125.03
200
400
600
800
1000
WINDOW:
-84.23/-22.86
162.73/162.36
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 5000 SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST
SCENARIO 3000 SCENARIO 01 - SUPPLY (1987) AND DEMAND (1990) - COST
DATE: 88 06 09
MODULE: 6.23
CRT SUN3...CG

Figure 57 Scenario Comparison - Network/Cost

the selected products, as a result of the construction of the new railway connections, and by using operating cost as impedance:

- Gypsum transportation did not exhibit significant changes in the selection of routes except inside its production zone, where a change from the highway mode to the Transnortheastern railway was observed (see Figure 58);
- Transportation of salt used the railway system for long-distance traffic toward the Southeast region, instead of coastal navigation (see Figure 59);
- Agricultural solid bulks transportation exhibited changes only in the railway circulation within the Northeast region, instead of using the coastline system (see Figure 60);
- Cement transportation shifted to the rail network (see Figure 61) with the construction of the Transnortheastern railway;
- The transportation of petroleum byproducts exhibited a new interior-bound movement starting at Salvador, through the Northeast railway system (instead of the coastal navigation used until then), due principally to the shortening of distances (see Figure 62).

Finally, the minimum-path tree was analyzed starting from Pirapora, taking into consideration distance, operating cost and time. The selection of Pirapora as origin was due to its importance and to its strategic location in the area of influence of the São Francisco Corridor, independent of the modal system used. This minimum-path tree indicates the routes with the lowest impedance, that reach all the other freight origin and destination centers, thus permitting an analysis of the different modes without quantifying the freight volumes assigned to the sections of the transportation network. These routes considered the transshipment operations in impedance evaluations.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MODES:
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LINK TYPES:
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SCENARIO 5000
PRODUCTS:
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SCENARIO 3000
PRODUCTS:
1
SCALE: 41.3
100
200
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WINDOW:
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162.73/162.36
DATE: 88 06 09
MODULE: 6.23
CRT SUN3.. ..cg
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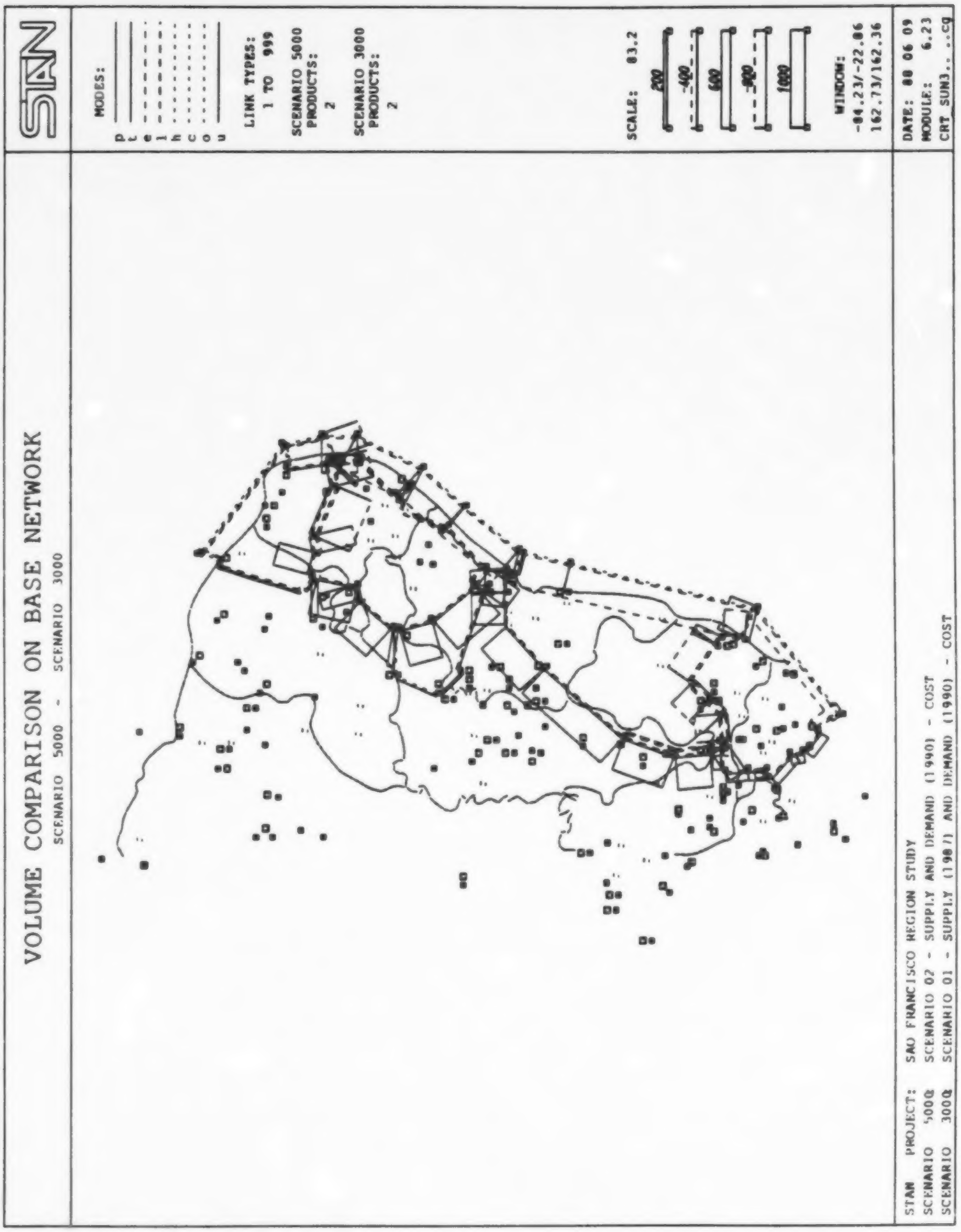
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 5000 SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST
SCENARIO 3000 SCENARIO 01 - SUPPLY (1987) AND DEMAND (1990) - COST

Figure 58 Freight Volume Comparison - Gypsum


VOLUME COMPARISON ON BASE NETWORK
SCENARIO 5000 - SCENARIO 3000
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MODES:
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t
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l
h
c
o
u
LINK TYPES:
1 TO 999
SCENARIO 5000
PRODUCTS:
2
SCENARIO 3000
PRODUCTS:
2
SCALE: 83.2
200
400
600
800
1000
WINDOW:
-84.23/-22.86
162.73/162.36
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 5000 SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST
SCENARIO 3000 SCENARIO 01 - SUPPLY (1987) AND DEMAND (1990) - COST
DATE: 88 06 09
MODULE: 6.23
CRT_SUN3.. ..cg

Figure 59 Freight Volume Comparison - Salt

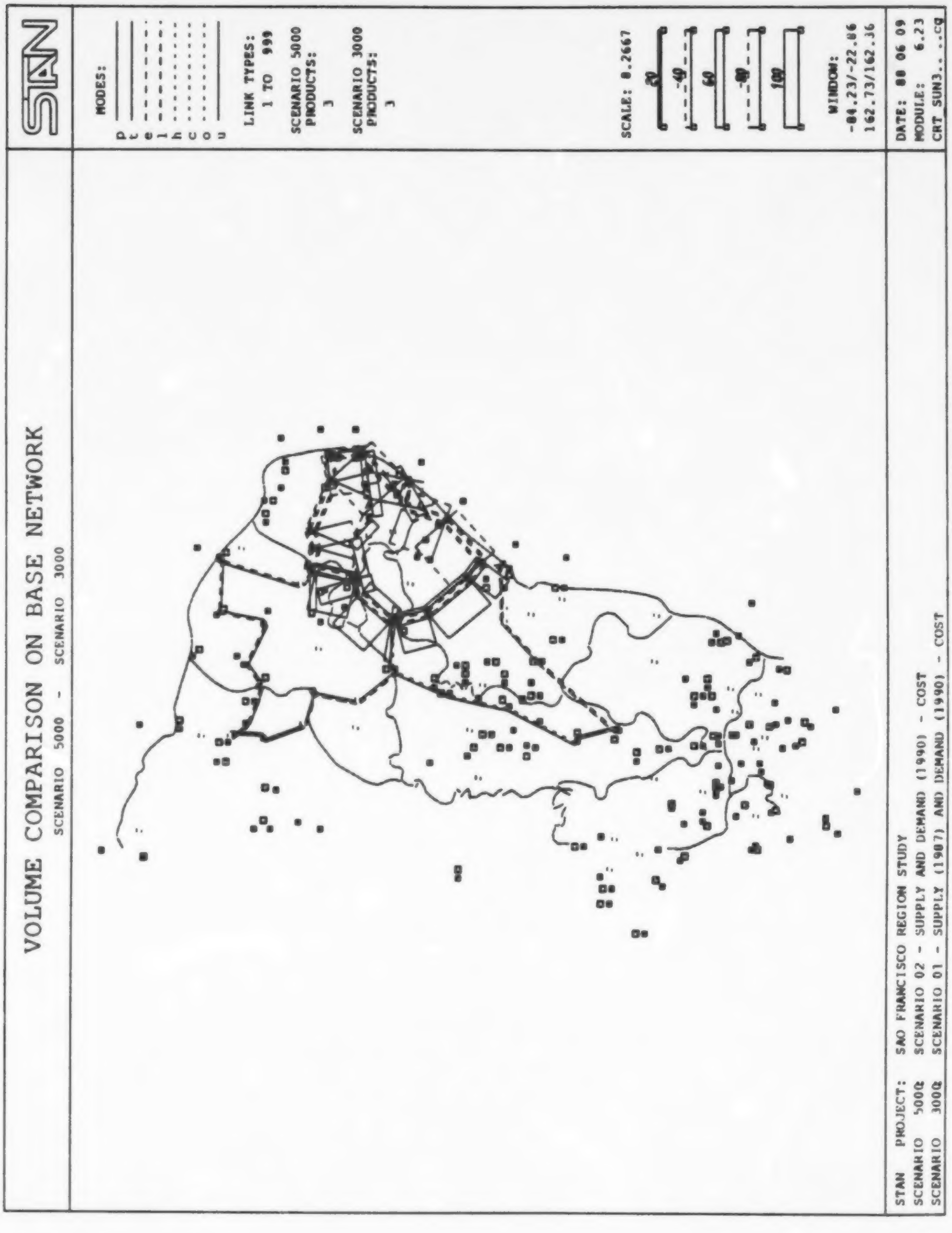
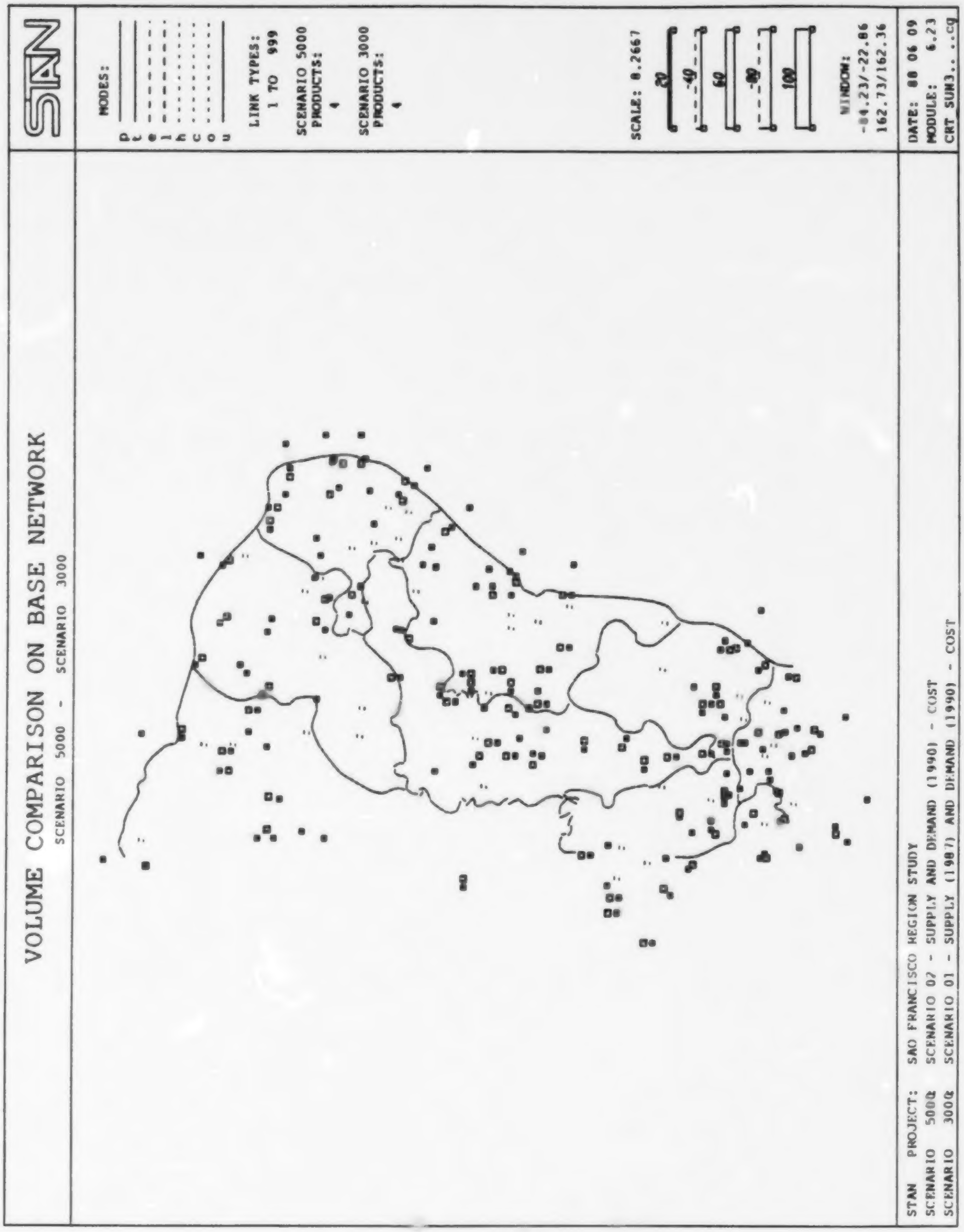

VOLUME COMPARISON ON BASE NETWORK
SCENARIO 5000 - SCENARIO 3000
STAN
MODES:
p
t
e
l
h
c
o
u
LINK TYPES:
1 TO 999
SCENARIO 5000
PRODUCTS:
3
SCENARIO 3000
PRODUCTS:
3
SCALE: 0.2667
20
40
60
80
100
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 09
MODULE: 6.23
CRT SUN3... .cg
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 5000 SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST
SCENARIO 3000 SCENARIO 01 - SUPPLY (1987) AND DEMAND (1990) - COST

Figure 60 Freight Volume Comparison - Agricultural Solid Bulks


VOLUME COMPARISON ON BASE NETWORK
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STAN
MODES:
p
t
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l
h
c
o
u
LINK TYPES:
1 TO 999
SCENARIO 5000
PRODUCTS:
4
SCENARIO 3000
PRODUCTS:
4
SCALE: 0.2667
20
40
60
80
100
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 09
MODULE: 6.23
CRT SUN3.. ..cg
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 5000 SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST
SCENARIO 3000 SCENARIO 01 - SUPPLY (1987) AND DEMAND (1990) - COST

Figure 61 Freight Volume Comparison - Cement

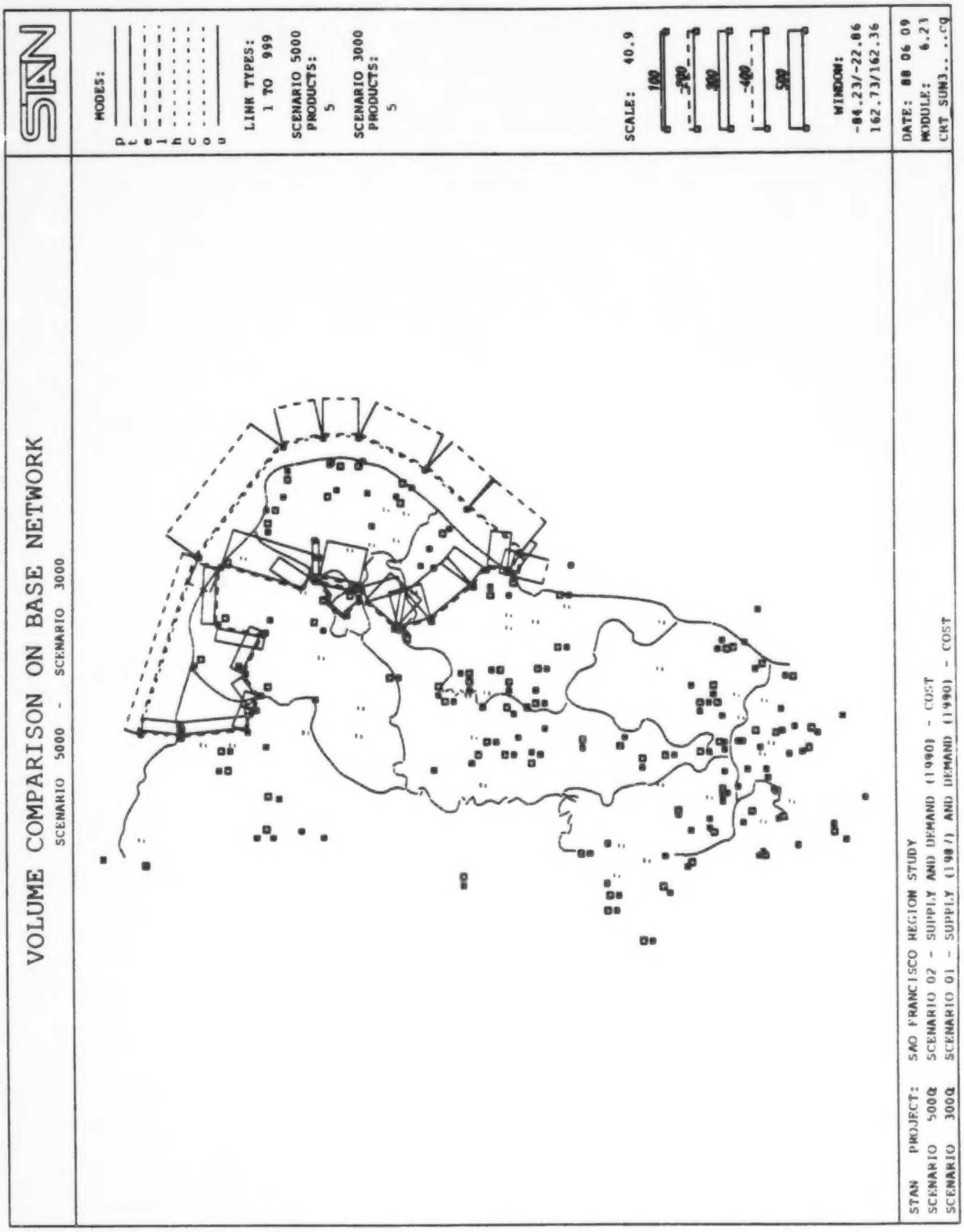
VOLUME COMPARISON ON BASE NETWORK
SCENARIO 5000 - SCENARIO 3000
MODES:
p
t
e
l
h
c
o
u
LINK TYPES:
1 TO 999
SCENARIO 5000
PRODUCTS:
5
SCENARIO 3000
PRODUCTS:
5
SCALE: 40.9
100
200
300
400
500
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 06 09
MODULE: 6.23
CRT SUN3...cg
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 5000 SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST
SCENARIO 3000 SCENARIO 01 - SUPPLY (1987) AND DEMAND (1990) - COST

Figure 62 Freight Volume Comparison - Petroleum Byproducts

According to distance, there was a significant participation of the highway mode within the Northeast and Center-South regions, whose connection was made through the São Francisco river and the railway line Salvador-Montes Claros (see Figure 63). The use of the highway system to reach Belém is evidenced, as well as the small integration with the coastal navigation in the Northeast. With the construction of the Transnortheastern railway, the distances were reduced, making rail competitive as compared to the highway system in the region, although without other influence on the remaining routes (see Figure 64). The transshipment operations did not imply additional distances.

According to unit operating costs, the predominance of the railway routes between inland centers was observed, as well as that of coastal navigation for the centers near the coastline (see Figure 65). The utilization of the São Francisco waterway was restricted to the centers within its area of influence, fed by the highway system of the region. The construction of the Transnortheastern railway induced a better utilization of the lines perpendicular to the coastline giving access to interior centers of the Northeast, independently of highway mode (see Figure 66).

According to time, the highway use is significant, both for long-distance traffic and for the internal supply of the Northeast and Center-South regions. The other modes are not used (see Figure 67).

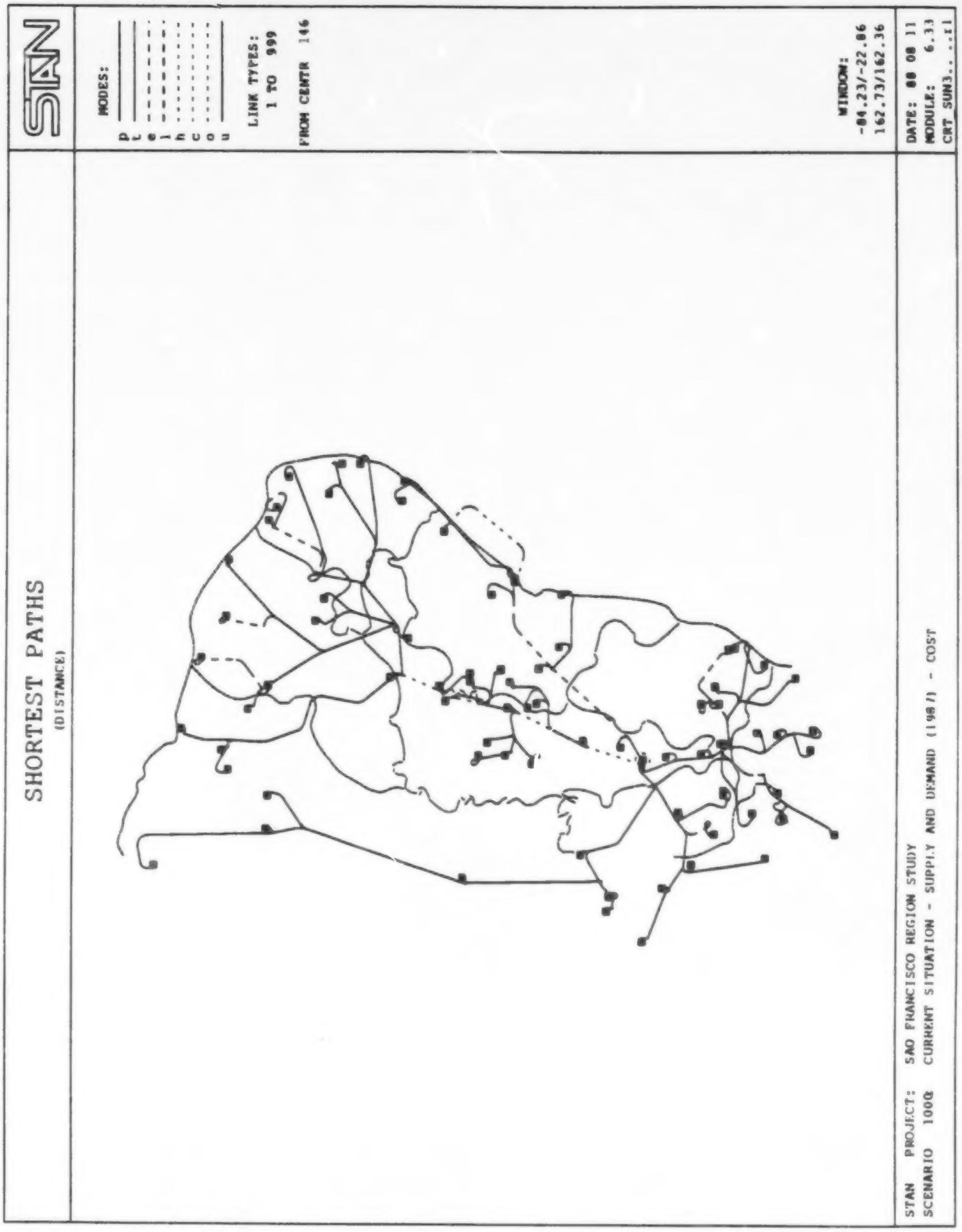
STAN
SHORTEST PATHS
(DISTANCE)
MODES:
p
t
e
l
h
c
o
u
LINK TYPES:
1 TO 999
FROM CENTR 146
WINDOW:
-84.23/-22.86
162.73/162.36
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100Q CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST
DATE: 88 08 11
MODULE: 6.33
CRT SUN3.. ..:1

Figure 63 Shortest Paths - Distance - Current Situation

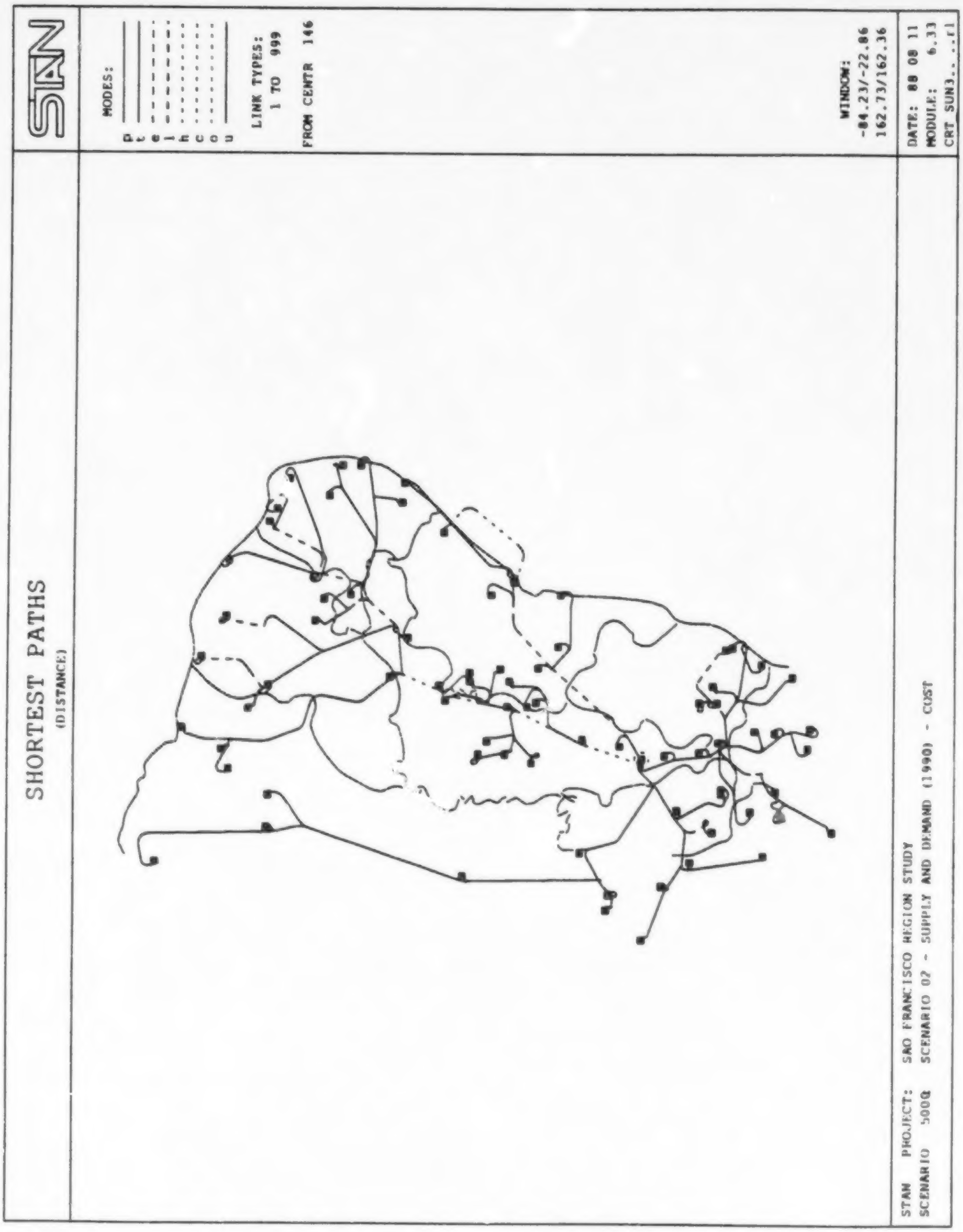
STAN
MODES:
p
t
e
l
h
c
o
u
LINK TYPES:
1 TO 999
FROM CENTR 146
WINDOW:
-84.23/-22.86
162.73/162.36
SHORTEST PATHS
(DISTANCE)
DATE: 88 08 11
MODULE: 6.33
CRT SUN3.. ..rl
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 500Q SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST

Figure 64 Shortest Paths - Distance - 1990 Situation

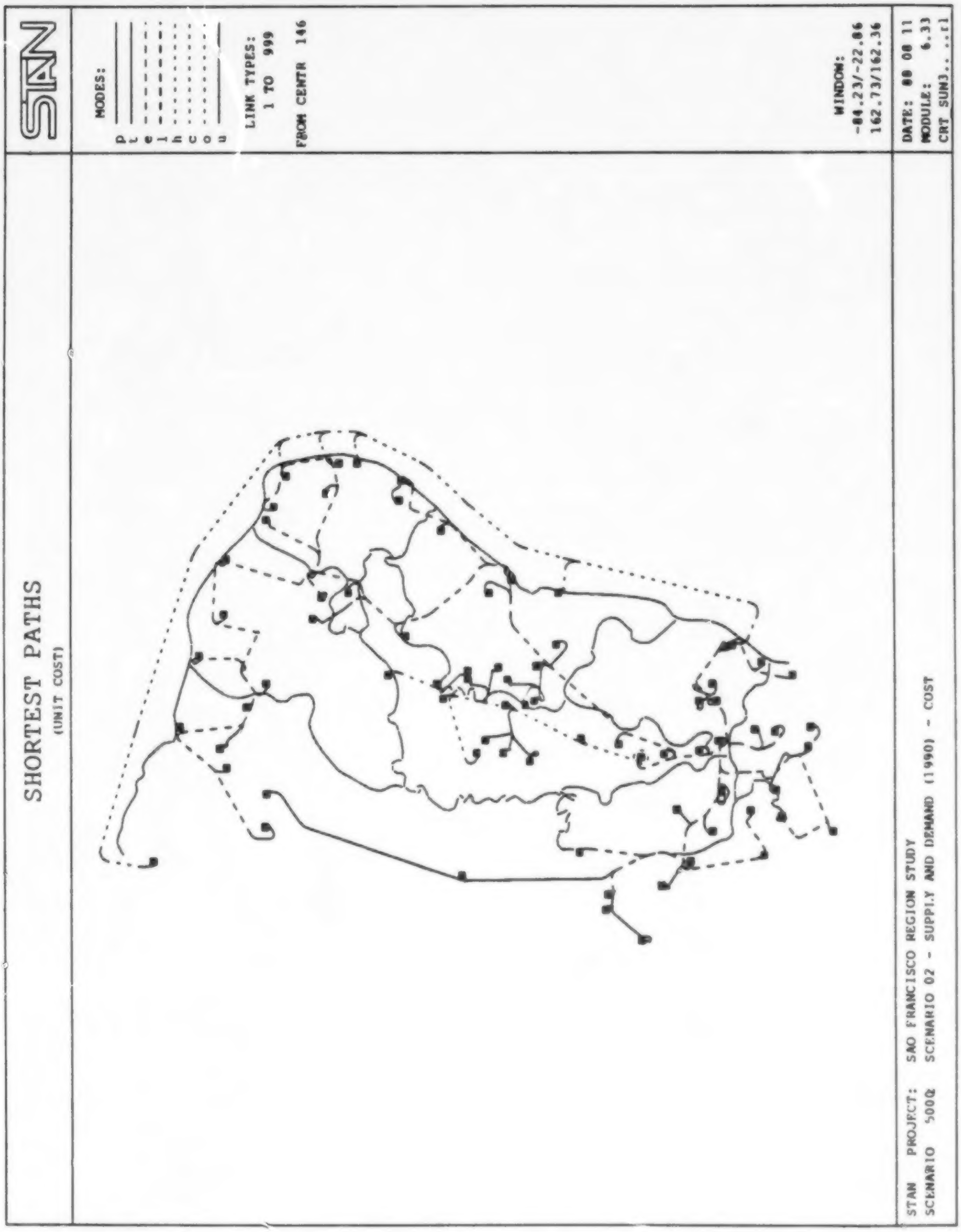
STAN
SHORTEST PATHS
(UNIT COST)
MODES:
p
t
e
l
h
c
o
u
LINK TYPES:
1 TO 999
FROM CENTR 146
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 08 11
MODULE: 6.33
CRT SUN3.....[1
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 500Q SCENARIO 02 - SUPPLY AND DEMAND (1990) - COST

Figure 65 Shortest Paths - Unit Cost - Current Situation

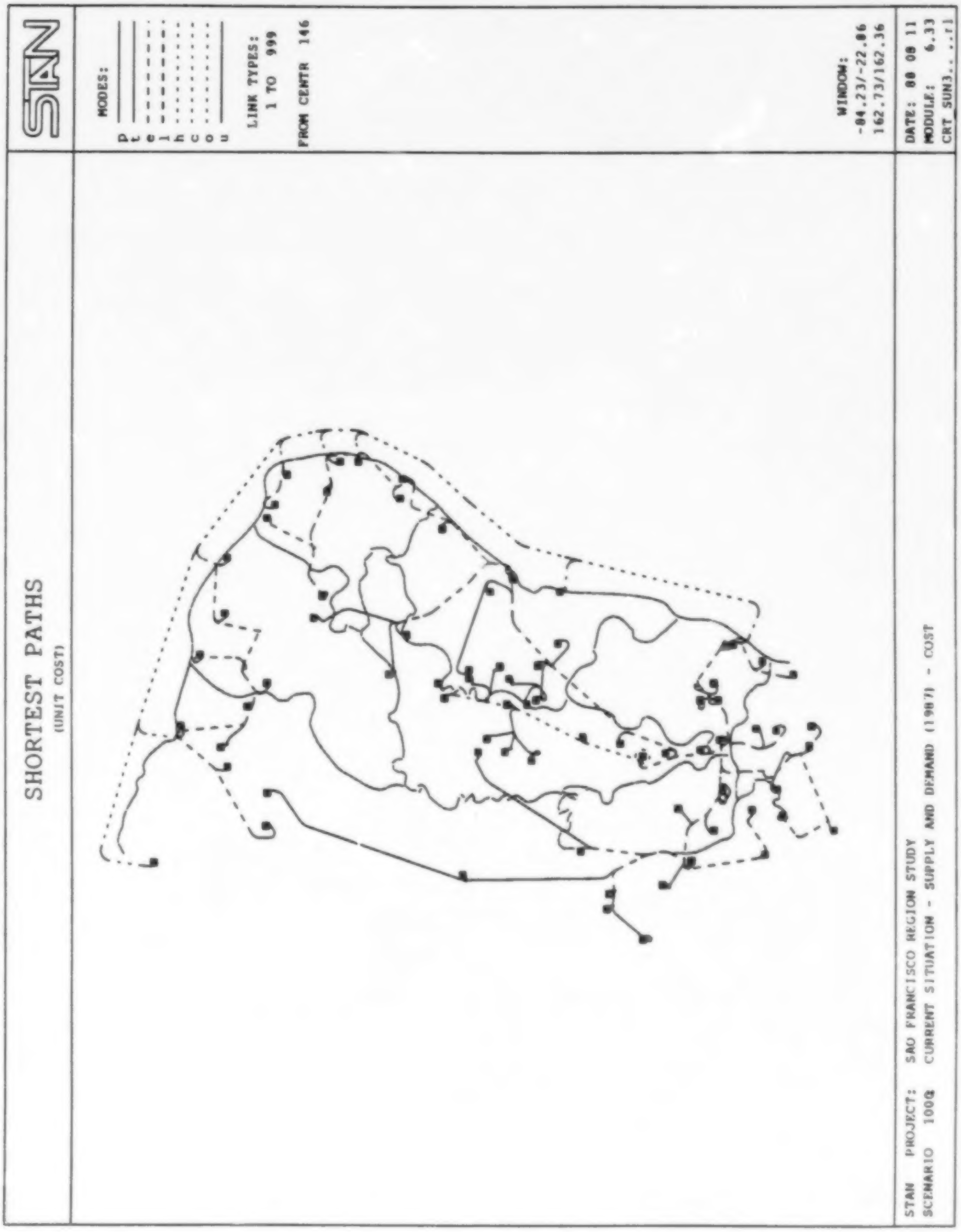
SHORTEST PATHS
(UNIT COST)
STAN
MODES:
p
t
e
l
h
c
o
u
LINK TYPES:
1 TO 999
FROM CENTR 146
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 08 11
MODULE: 6.33
CRT SUN3.....rl
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 100G CURRENT SITUATION - SUPPLY AND DEMAND (1987) - COST

Figure 66 Shortest Paths - Unit Cost - 1990 Situation

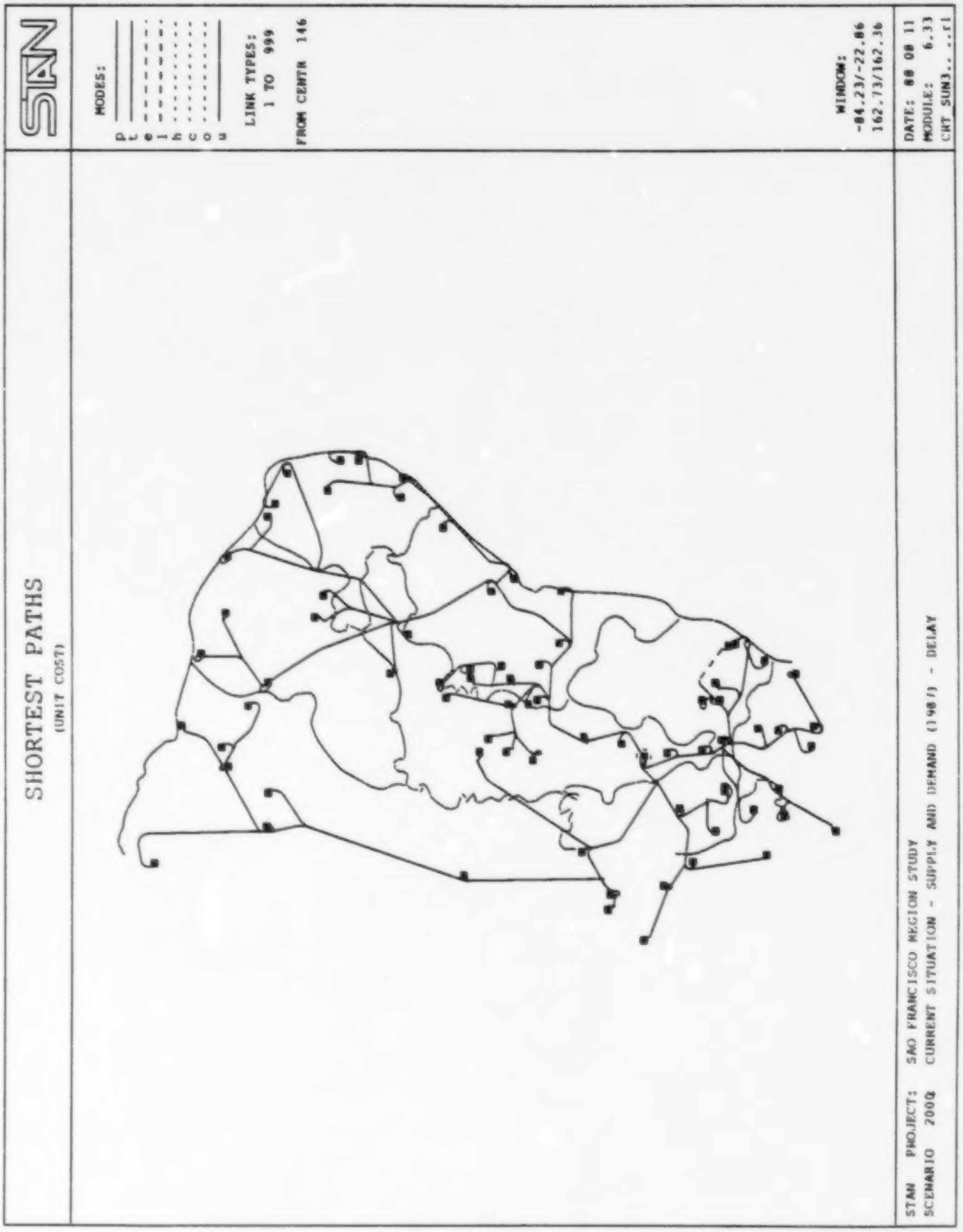
STAN
SHORTEST PATHS
(UNIT COST)
MODES:
p
t
e
l
h
c
o
u
LINK TYPES:
1 TO 999
FROM CENTR 146
WINDOW:
-84.23/-22.86
162.73/162.36
DATE: 88 08 11
MODULE: 6.33
CRT_SUN3.. ..rl
STAN PROJECT: SAO FRANCISCO REGION STUDY
SCENARIO 2000 CURRENT SITUATION - SUPPLY AND DEMAND (1987) - DELAY

Figure 67 Shortest Paths - Time - Current Situation

CHAPTER FOUR

CONCLUSIONS AND PROSPECTS

The STAN system proved to be an analysis tool of great potential for the strategic planning of the Transportation Sector. The application to the analysis of several scenarios relative to the São Francisco Corridor demonstrated the procedures required for its utilization and of the input data required. The analysis of its results were shown to be valuable for assessing investments and actions relative to the Sector. It is worth stressing that this application had a practical purpose as part of the study to make this strategic corridor operational.

In effect, the utilization of the STAN system extrapolates the analysis of flow distribution through the transportation network and permits the multi-modal network to be characterized in terms of inventory (geometry, maintenance state, etc.) and utilization under various demand hypotheses. It also allows the transportation demand information to be validated by product in terms of projected flow estimates. The visualization of the initial data and of the results by means of interactive graphic capabilities which facilitate the user interactions enhance and complement its advantages, by facilitating the access to the system by transportation technicians. It is important to note that the assignment algorithm included in the system allows non-linear effects present in transportation activities, such as economies of scale and congestion phenomena, to be introduced. This type of relation was not yet empirically explored in Brazil.

The integration of the STAN system with tactical-operating planning models constituted an essential theoretical evolution for the development programs of the Sector. On the other hand, the continuity of its utilization requires a permanently updated information system, instead of only occasional and specific applications. The STAN system certainly represents a technological advance in transportation and is not restricted to the application in the national context.

In terms of prospective applications, there is a line for immediate action and another for long-term action. In the first case, STAN will be applied to the strategic corridors program, in the studies for making them operational, and to GEIPOT's in-process projects as a procedure capable of assigning multi-commodity freight to a multi-modal transportation network. In the second case, there is the intention of introducing it in the Transportation Sector Development Program (PRODEST) and using its analysis potential for strategic planning and requiring continuous reevaluations in three-year periods.